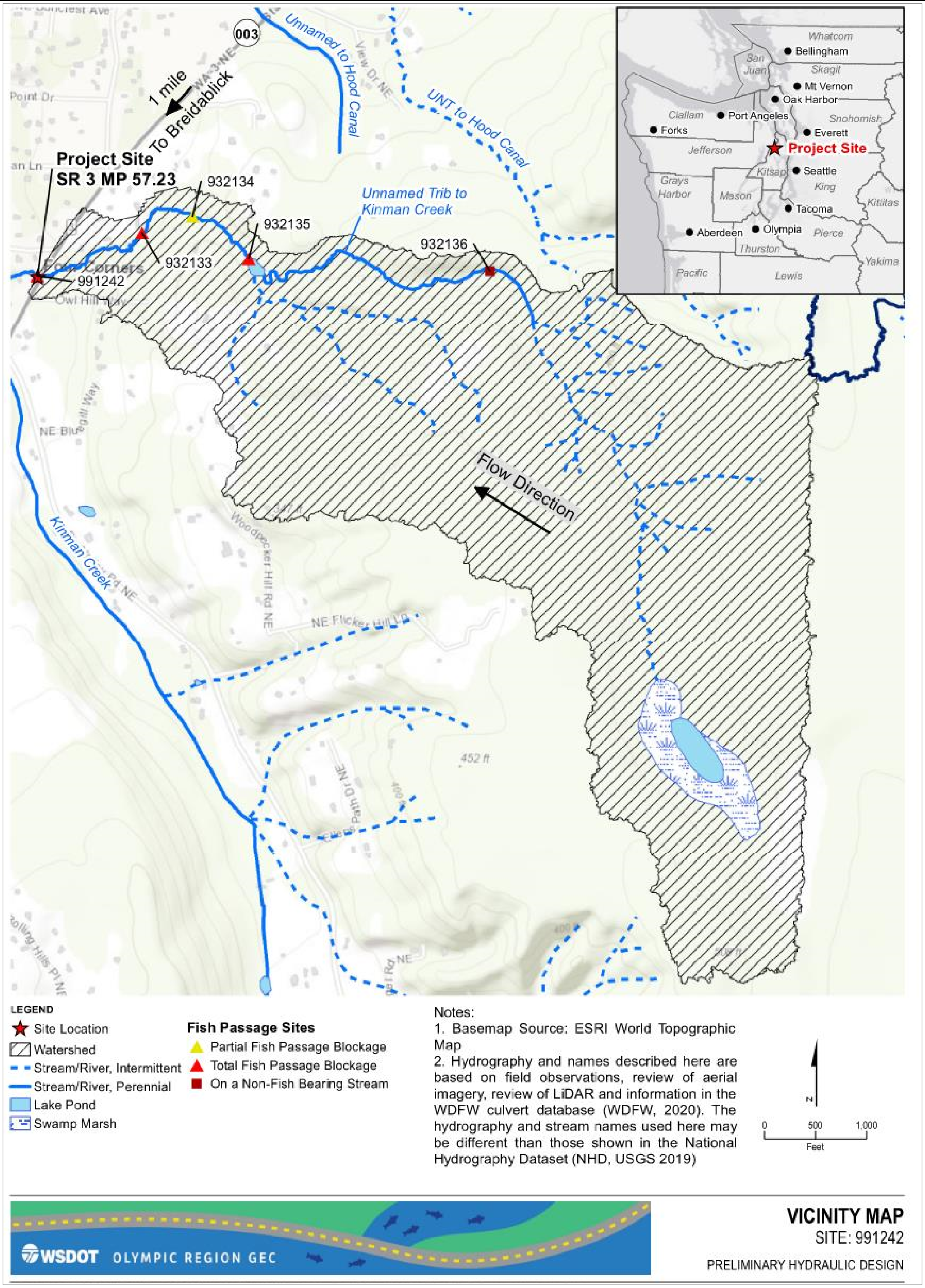
Hydraulics Section	Medium Complexity Stream Summary	Date: 1/19/23
	Project Name: PHD Unnamed Tributary to Kinman Creek	WDFW ID Number: 991242
	Project Office: Jacobs Engineering Group, Inc. Bellevue WA	County: Kitsap
	Stream Name: Unnamed Tributary to Kinman Creek	State Route/MP: SR 3 MP 57.23

Brief Project Summary

The Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at the State Route (SR) 3 crossing of Unnamed Tributary to Kinman Creek (UNT to Kinman Creek) at milepost (MP) 57.23 within WSDOT's Olympic region. The existing structure at that location has been identified as a fish barrier by the Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (ESO) (site identifier [ID] 991242), and has an estimated 5,676 linear feet (LF) of habitat gain (WDFW 2004).

UNT to Kinman Creek exhibits a meandering planform, with a sinuosity of roughly 1.05 to 1.10 and has a bankfull width of 6 feet as identified during Site Visit 3 (see attached field notes). Meandering is limited by incision into the alluvial fan surface and outwash surface.

The proposed project will replace the existing 36-inch-diameter, 84-foot-long precast concrete culvert with a structure designed to accommodate a minimum hydraulic width of 18 feet. The proposed structure will be approximately 90 feet long and the project is proposed to include approximately 219 feet of channel grading (including the structure length). The proposed structure is designed to meet the requirements of the federal injunction using the unconfined bridge design criteria as described in WDFW's Water Crossing Design Guidelines (WCDG; Barnard et al. 2013). This design also meets the requirements of the WSDOT *Hydraulics Manual* (WSDOT 2022a). The crossing location can be seen in the Vicinity Map below.



Vicinity map

Design Elements	
Floodplain Utilization Ratio	FUR: 3.7 ☒>3.0 (Unconfined) ☐<3.0 (Confined)
Design Methodology	☐Stream Simulation ☒ Bridge
Structure Length	90 ft Long Structure? ☐ Yes ☒ No
Preliminary Scour	2.2 ft (2080, 100-year)
Migration Risk	☒Low ☐ Not Low Scour Countermeasures? ☐ Yes ☒ Possibly ☐ No
Gradient	3.0 % Downstream 1.6% Upstream 1.6% Reference Reach

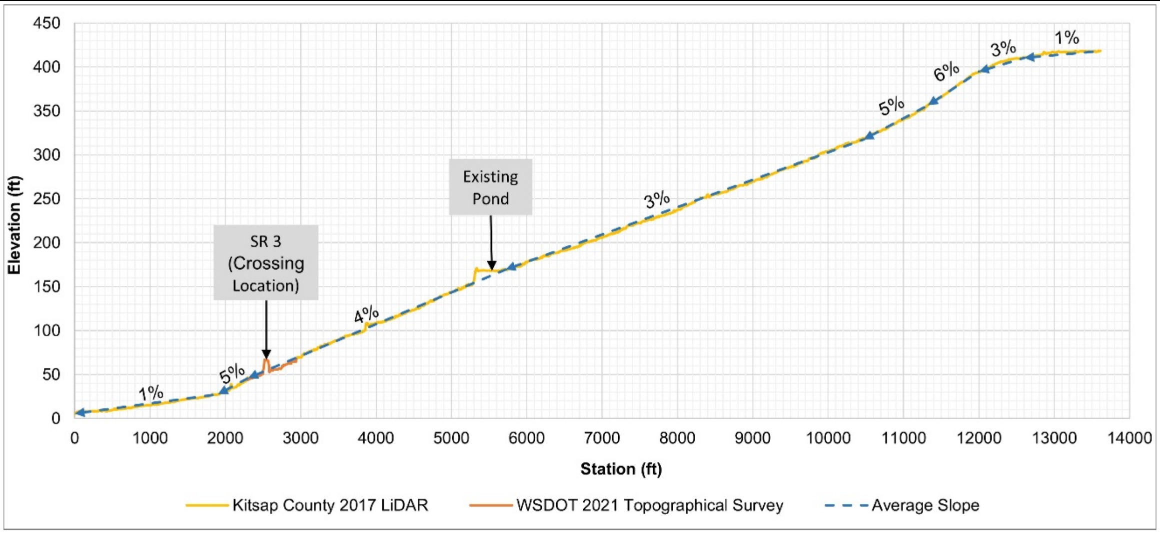
Element	Requirement	Proposed
Channel Morphology	Glide-Pool	Glide-Pool
Minimum Hydraulic Width	Eq. 3.2 of WCDG = 10.0ft	18.0 ft for geomorphic processes and to avoid entrainment
Slope	1.2% to 2% (0.75% to 125% of Ref Reach)	Glides= 1.8% Slope Ratio = 1.13
Freeboard above the 100-year	2.0 ft	Minimum 2.0 ft with recommended 6.0 ft maintenance clearance

Long Profile

The vertical stability of the channel was assessed using the longitudinal profile (figure below) evaluation of upstream mass-wasting, and field indicators. The longitudinal profile is straight (neither convex nor concave) with the profile slope generally between 3 to 5 percent. At the reach scale, the overall shape of the profile is straight, but it exhibits steps. The steps in the profile enable lower-gradient channel types, such as glides, to persist by slowing flow behind small accumulations of wood that function as steps. These steps act as minor grade control structures. Longevity of these steps is relatively short, but there are sufficient steps to hold the overall grade and likely sufficient recruitment of woody material to reform steps.

The steps in the profile also allow for finer grain sediments to persist in the channel than would otherwise be present at these gradients. Within the reference reach, extensive dunefields were observed. In other parts of the reference reach, the bed material is matrix-supported, meaning that gravel clasts are commonly not in contact with other gravel clasts and are separated by sand and finer material.

These abundant sediments may have their source in upstream mass-wasting deposits. Hillshade imagery derived from LiDAR (USGS and Quantum Spatial 2018) show large arcuate head scarps at the top of the hillslopes on either side of the channel, approximately 1,500 feet upstream of the crossing. These scarps indicate the approximate initiation point of the mass-wasting event. The released material is deposited in the channel and valley and is periodically transported downstream. Without a field reconnaissance, the extent of the sediment source cannot be verified, but it is likely that the abundance of observed finer sediments are related to these deposits. However, the slope of the channel and active engagement with the floodplain allow for in-channel transport of sediments and floodplain deposition of overbank sediments. There is one passage barrier downstream of the scarps; however, given the sands observed in the channel, this barrier does not appear to restrict the movement of sand-sized sediments. Larger sediments may be trapped behind the upstream barrier.



Watershed-scale longitudinal profile

Hydrology

Peak flows for Unnamed Tributary to Kinman Creek at SR 3

Mean Recurrence Interval	Selected Method - MGSFlood (cfs)	Check Method - USGS Regression Equation (Region 3) ([PI_l], Q_u, [PI_u] in cfs)
2	12	[8] 15 [31]
10	30	[15] 31 [65]
25	37	[18] 40 [86]
50	49	[20] 46 [103]
100	54	[23] 53 [120]
500	57	[28] 69 [172]
Projected 2080, **100**	**(84**; **+56%)**	**([43] 108 [268]**; **+56%)**

Sediment Size Summary

Comparison of observed and proposed streambed material

Sediment size	Observed diameter for glides (in)	Observed diameter for riffles (in)	Proposed diameter (in)	Meander bar/ coarse band head diameter (in)	Meander bar/ coarse band tail diameter (in)
D_{16}	0.02	0.1	0.1	0.6	0.5
D_{50}	0.04	0.4	1.2	13.0	3.0
D_{84}	0.3	1.3	2.6	16.4	11.0
D_{95}	1.0	2.1	3.5	17.5	15.0
D_{100}	5.5	3.0	4.0	18.0	18.0

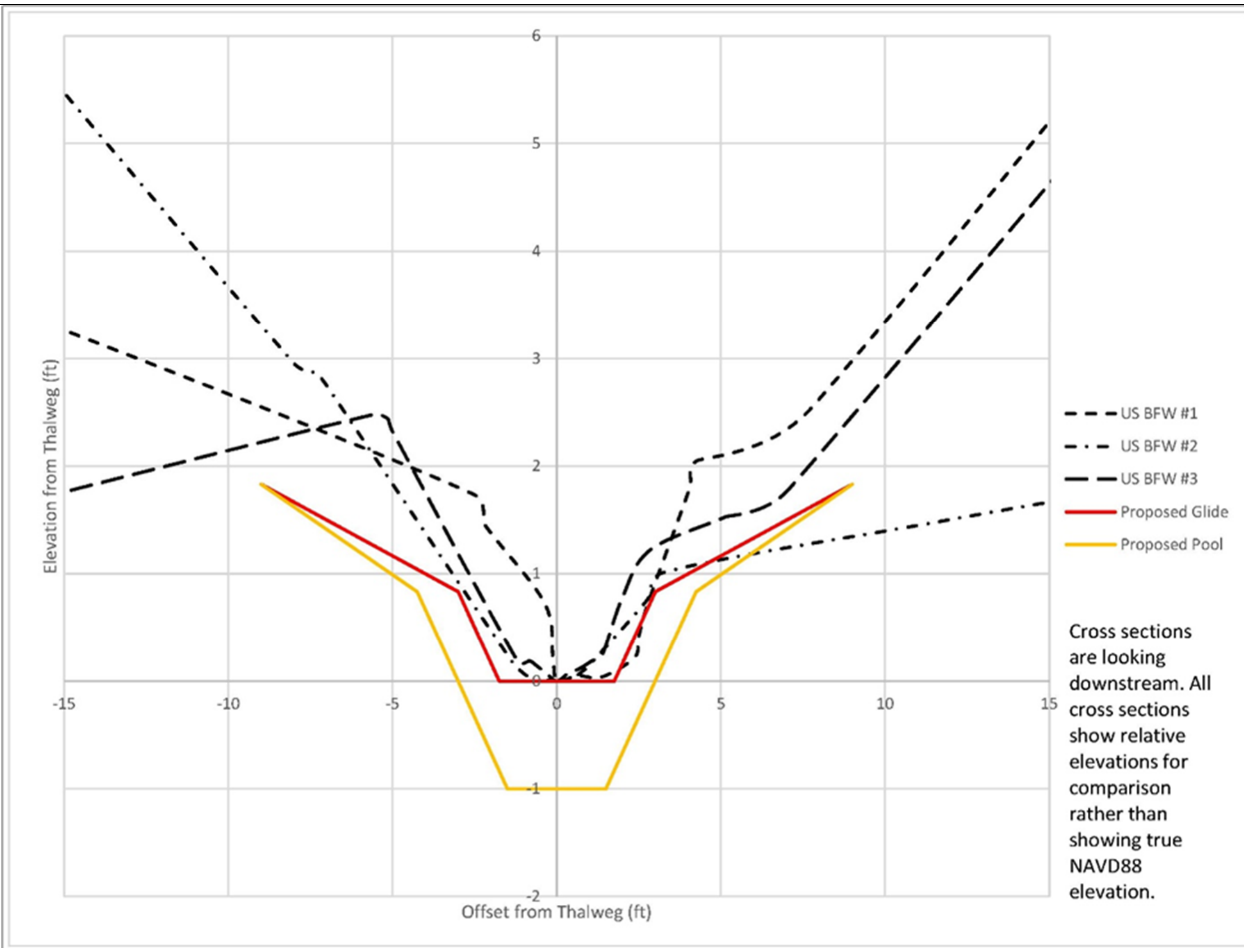
Streambed material in the glide reaches is dominated by sand and silt (D_{50} <0.04 inch), and riffles are dominated by small gravel (D_{50} of 0.2 inch). Due to the small size of the existing material and using the approach above (specifically using the Modified Critical Shear Stress Design methodology), the suggested SBM is 50 percent WSDOT 4-inch streambed cobbles with 40 percent WSDOT standard streambed sediment and 10 percent streambed sand for the proposed main channel, as outlined in the table above. The table above summarizes the observed grain size distribution versus the proposed grain size distribution. The proposed D_{50} is three times the observed riffle D50. The observed riffle D50 is calculated from two pebble counts, each of which had a significant mode (10 to 12 percent) in sand-sized and finer sediments. This sand-sized and smaller fraction results in a lower D_{50} grain size, lower than if the sand-sized fraction had been excluded. These factors result in a larger than observed D_{50} grain size. However, the observed and calculated D_{16} and D_{100} grain sizes are approximately the same. The D_{84} of the proposed streambed material remains stable up to and through the 2-year event. At flow events higher than the 2-year event, it is anticipated that transported bed material will then be replaced from the stored sediment upstream of the crossing. The initial mobility of the streambed allows for the channel to naturally adjust over time. This means the channel widths will begin to increase while channel depths begin to decrease; these changes will result in a decrease in shear stresses and therefore less mobile streambed material.

The crossing will have several meander bars and half-channel coarse bands along the crossing walls to avoid entrainment, maintain channel shape, and maintain the sinuous thalweg over time. Current guidance on meander bar design (Heilman 2022) suggests that the head of the meander bar should be stable at the 100-year flow and the tail should be at least 50 percent or greater than the D84 grain size. The proposed material for the meander bars (Table above) meets these requirements. Initial calculations suggest the use of 10 percent WSDOT 12-inch streambed cobbles, 60 percent one-man boulders (12 to 18 inches in size), and 30 percent WSDOT standard streambed sediment for the heads of these larger features. Additionally, initial calculations suggest the use of 60 percent WSDOT 12-inch streambed cobbles, 10 percent one-man boulders (12 to 18 inches in size), and 30 percent WSDOT standard streambed sediment for the tails of these larger features. The design team predicts that this material is oversized due to the limitations of the calculations used at this PHD level of analysis. The proposed streambed mix for meander bars and half-channel coarse bands should be evaluated during the scour analysis in the FHD. Additional pebble counts should also be performed at existing step-pools within the reference reach to help determine appropriate material sizing in these locations. Additionally, grab samples would help show what the stream base sediments are and are recommended for the FHD.

Channel Shape

Per the WCDG (Barnard et al. 2013) the planform and shape of each subreach within the proposed design were designed to mimic the reference reach with adjustments based on engineering and geomorphic judgements. The proposed glide geometry includes a 6-foot BFW, an 0.8-foot bankfull depth, and floodplain benches on both sides to mimic the upstream reference reach. The bottom of the channel is flat, the banks are sloped at 1.5:1, and the floodplain is sloped at approximately 10:1. The spacing of the glides is within the range of spacing observed in the reference reach (25 to 50 feet). The steep bank slopes mimic what was seen in the reference reach; however, this can be difficult to construct and maintain. As such, fabric-encapsulated soil lifts should be considered during the final hydraulic design (FHD). The slope of the floodplain was selected to mimic the existing floodplain slopes in the reference reach.

The proposed pool geometry includes an 8.5-foot BFW, a 1.8-foot bankfull depth, and floodplain benches on both sides that align with the proposed glide geometry. The bottom of the pool is flat, the banks are sloped at 1.5:1, and the floodplain slopes at approximately 10:1. The figure below shows the proposed typical cross sections superimposed with existing survey cross sections for comparison.



Proposed cross section superimposed with existing survey cross sections

Habitat Complexity

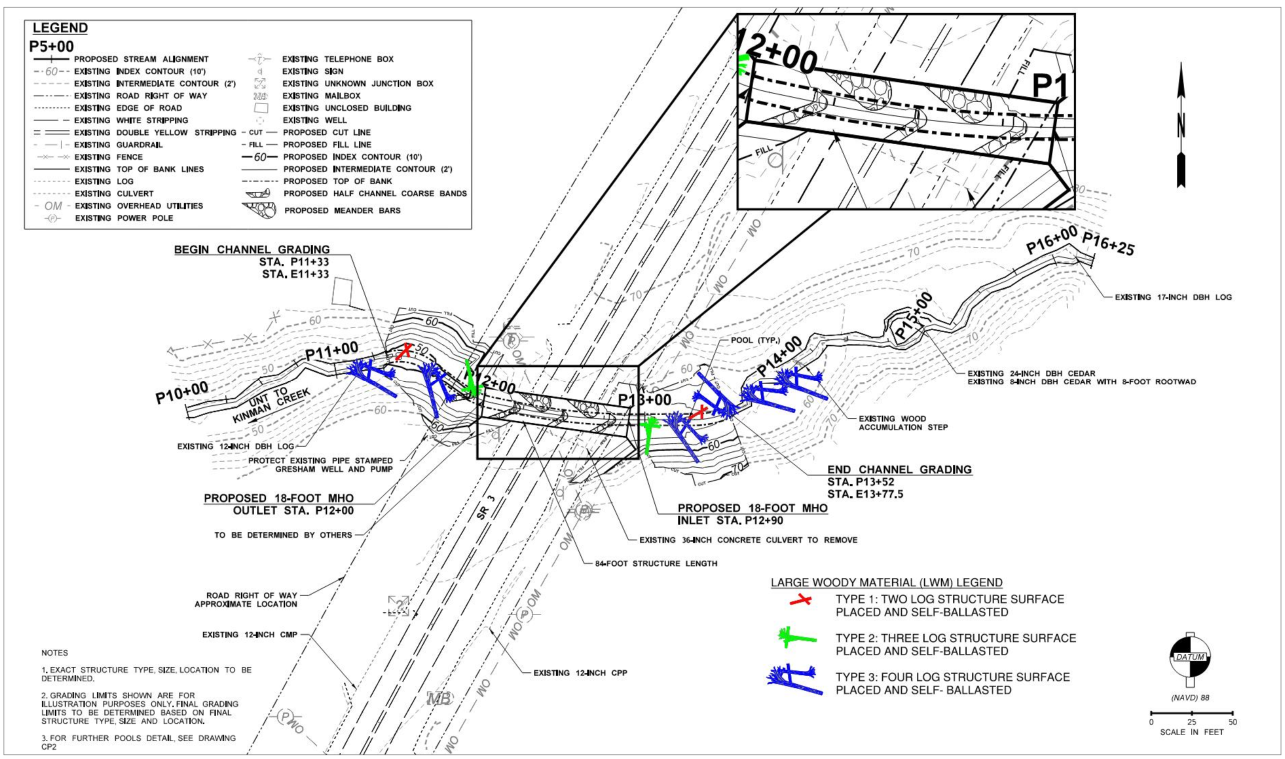
Complexity in the crossing and regraded reach will be provided by a slightly sinuous planform, LWM structures placed upstream and downstream of the crossing, and habitat and channel-forming features in the crossing. The LWM structures are placed to engage with the channel beginning at low flow. Meander bars (above-grade structures designed to facilitate flow turning and meander bends developing) are placed on the inside of meander bends, inside the crossing. Half-channel coarse bands (below-grade structures designed to prevent channel incision and realignment against the structure wall) are placed on the left bank of the channel,
inside the crossing. Crests within the profile are created by deformable steps. These steps mimic the observed steps, which commonly consist of tree roots and organic debris accumulations and enable flatter gradient glides to form, just as observed in the reference reach.

Half-channel coarse bands within the structure mimic the natural steps observed in the reference reach and will be used to prevent bed incision at pools and prevent realignment adjacent to the structure wall. The proposed meander bars provide habitat value through localized scour pools and flow deflection, which creates variable flow patterns and encourages the development of meander bends. These meander bars are located to ensure that the glides do not align themselves along the structure wall between the coarse bands. The meander bar elevations vary from the 10-year elevation at the structure wall to the 2-year elevation at the top of the channel bank.

Deformable steps are crests in the profile that slow upstream flow and facilitate pre-formed pool maintenance immediately downstream. They are formed of coir fabric rolled around a core of coarse streambed material with adequate fines to prevent flows from going subsurface through the step. The deformable step is underlain by coarse band, which provides a stable foundation for the step. Over time, the step may accrete small woody material and organic debris, similar to steps observed in the reference reach. Step height is limited due to the maximum hydraulic drop being limited to 0.8 feet as specified in WDFW's WCDG (Barnard et al. 2013) to prevent fish stranding.

The existing LWM is limited both upstream and downstream of the existing culvert with no pieces providing the key piece function. The proposed design for the LWM (figure below) shows the proposed 30 pieces of wood to be placed within the 219-foot graded channel, with exception of a 90-foot segment for the roadway crossing. No LWM is recommended to be placed under SR 3 due to the size of the crossing. As of this time, the LWM design is conceptual and will need to be field verified in the FHD. The proposed design meets and exceeds the 75th percentile of the number of key pieces and total number of pieces as estimated by Fox and Bolton (2007). However, due to the small size of UNT to Kinman Creek, the proposed design does not meet the 75th percentile but does meet and exceed the 50th percentile of the total volume suggested by Fox and Bolton (2007).

At the FHD, the orientation of structures will be refined for additional functions, such as creating undercut banks, and for additional means of anchoring, such as passive burial. All structures will be confirmed to remain stable up to and through the 100-year flow event by either anchoring or by virtue of the structures' weight, configuration, and orientation.



Conceptual layout of habitat complexity

Attachments:

PHD

Complexity Form with Relevant PHD Sections

WSDOT Hydraulics Section	Project Complexity Review	Prepared By: M. Kinsey	Page: 1
	Project Name: PHD Unnamed Tributary to Kinman Creek	Date: 1/19/23	
	Stream Name: Unnamed Tributary	WDFW ID Number: 991242	
	Tributary to: Kinman Creek	State Route/MP: SR 3 MP 57.23	

General Instructions:

The complexity form that was filled out during Site Visit 3 (and any updates between Site Visit 3 and PHD) is used to fill in the Levels of Complexity below. WDFW will utilize this form to review the relevant sections of the PHD and provide comments based on Requirements.

The relevant sections listed below not bolded are standard from this template. Any sections listed in bold are sections that are added for consideration by the design team to the element to provide further clarity.

Category	Project Elements	Levels of Complexity			Relevant PHD Section(s)
		Low	Med	High	
Stream Design Factors (alignment, profile, bed mix)	Channel realignment	x			4.1.2
	Stream grading extents	x			Appendix C; Section 4
	Expected stream movement (migration)	x			2.7.5, **7.1**
	Gradient (morphology)		x		2.6.4, **2.6.2**
	Slope ratio	x			4.1.3
	Sediment supply	x			2.3, **2.7.4, 4.2.3.2**

Category	Project Elements	Levels of Complexity			Relevant PHD Section(s)
		Low	Med	High	
Structure Factors	Stream size and bankfull width	x			Section 2, **4.1.1**
	Meeting requirements for freeboard	x			4.2.3
	Fill depth above barrier	x			4.2.3
	Risk of degradation/aggradation	x			7, **2.7.4**
	Long culvert criteria/openness ratio	x			4.2.4
	Channel confinement & Floodplain Utilization Ratio (FUR)		x		2.7.2.1, Entire Section 5, Appendix E, Appendix H, Appendix I
	Meeting Stream Simulation	x			Summarized in table
	Tidal influence	x			N/A for medium complexity sites as this automatically kicks project to high complexity
	Alluvial fan	x			N/A for medium complexity sites as this automatically kicks project to high complexity
	Presence of other barriers nearby	x			Section 2 throughout, potentially Sections 4 and 5 if barrier influences design
	Potential for backwater impacts				Section 6
	Presence of infrastructure nearby		x		2.6.2 Existing Conditions
	Need for bank protection	x			8, Appendix M
	Geotech or seismic considerations		x		2.3, **Section 7**

SR 3 MP 57.23 Unnamed Tributary to Kinman Creek (WDFW ID 991242): Preliminary Hydraulic Design Report

Julie Heilman, PE, State Hydraulics Engineer
Certification FPT22-00157
Y-12554 Olympic Region GEC

PHD LEAD PROFESSIONAL ENGINEER:
Karen Williams, PE, PhD., Sr. Geomorphologist/Engineer, FPT20-15358, Jacobs

AUTHORING FIRM PHD QC REVIEWER(S):
Nich VanBuecken, PE, Sr. Stream Restoration Engineer, FPT20-08789, Jacobs

OLYMPIC REGION GEC FISH PASSAGE AND STREAM DESIGN ADVISOR (SDA):
Jeff Kamps, Sr. Stream Restoration Designer, FPT20-46875, Jacobs

JACOBS ENGINEERING GROUP INC.

Michelle Kinsey, EIT, Stream Restoration Engineer, FPT20-10786
Reilly Holland, EIT, Stream Restoration Engineer, FPT20-36477
Brandon Werner, EIT, Hydraulic Engineer, FPT20-34376
Sage Jensen, Senior Biologist, FPT20-09346

ROLES AND RESPONSIBILITIES FOR THIS PHD

The roles and responsibilities of the key individuals in developing this Preliminary Hydraulic Design (PHD) are defined as follows for the Olympic Region GEC:

PHD Lead PE
Responsibility: Water Resources Professional Engineer in responsible charge of this Hydraulic Design Report, including all information, calculations, assumptions, modeling, professional judgment, and commitments contained in the main report and appendices.

Authoring Firm PHD QC Reviewer(s)
Responsibility: Qualified independent individual(s) responsible for the detailed checking and reviewing of hydraulic and stream design documents prepared by the authoring firm, including all information, calculations, assumptions, modeling, professional judgment, and commitments contained in the main report and appendices. Before submittal to the GEC, the authoring Firm Quality Control (QC) Review shall be performed in accordance with the QC methods identified in the quality assurance document Technical Verification Form. The QC methods are defined in the Olympic Region GEC Quality Management Plan Section 5.3 and the Quality Management Plan Supplement developed specifically for Y-12554 Task AC.

Olympic Region GEC Fish Passage/Stream Design Advisor
Responsibility: Water Resources Professional Engineer providing mentorship, process oversight, quality check issue resolution, and recommendations in the approach to hydraulic analysis and design performed by the **PHD Lead PE**. Before submittal of draft deliverables from the GEC to either the PHD Lead or WSDOT Headquarters, the Olympic Region GEC Fish Passage/Stream Design Advisor will review and refine GEC comments and confirm GEC comment resolution by the **PHD Lead PE**.

Americans with Disabilities Act (ADA) Information

Materials can be made available in an alternative format by emailing the WSDOT Diversity/ADA Affairs Team at wsdotada@wsdot.wa.gov or by calling toll free: 855-362-4ADA (4232). Persons who are deaf or hard of hearing may contact that number via the Washington Relay Service at 7-1-1.

Title VI Notice to Public

It is Washington State Department of Transportation (WSDOT) policy to ensure that no person shall, on the grounds of race, color, national origin, or sex, as provided by Title VI of the Civil Rights Act of 1964, be excluded from participation in, be denied the benefits of, or be otherwise discriminated against under any of its federally funded programs and activities. Any person who believes his/her Title VI protection has been violated may file a complaint with WSDOT's Office of Equal Opportunity (OEO). For Title VI complaint forms and advice, please contact OEO's Title VI Coordinator at 360-705-7082 or 509-324-6018.

Contents

Figures

Tables

1 Introduction

To comply with United States et al. vs. Washington et al., No. C70-9213, Subproceeding No. 01-1 dated March 29, 2013 (a federal permanent injunction requiring the State of Washington to correct fish barriers in Water Resource Inventory Areas [WRIAs] 1 through 23), the Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at the State Route (SR) 3 crossing of the Unnamed Tributary to Kinman Creek (UNT to Kinman Creek) at milepost (MP) 57.23 within WSDOT's Olympic Region. The existing structure at that location has been identified as a fish barrier by the Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (ESO) (site identifier [ID] 991242) and has an estimated 5,676 linear feet of habitat gain (WDFW 2004).

Per the federal injunction and in order of preference, fish passage should be achieved by (1) avoiding the necessity for the roadway to cross the stream, (2) use of a full-span bridge, or (3) use of the stream simulation methodology. WSDOT evaluated the crossing and is proposing to replace the existing crossing structure with a structure designed using the unconfined bridge design criteria as described in further detail in Section 4.2.1.

The crossing is located in Kitsap County, approximately 1 mile north of Breidablick, Washington, in WRIA 15 (Washington State Department of Ecology [Ecology] n.d.). The highway runs in a northeast-southwest direction at this location and is about 600 feet from the confluence with Kinman Creek. UNT to Kinman Creek generally flows from east to west, beginning approximately 2 miles upstream of the SR 3 crossing (Figure 1).

The proposed project will replace the existing 36-inch-diameter, 84-foot-long precast concrete culvert with a structure designed to accommodate a minimum hydraulic width of 18 feet. The proposed structure is designed to meet the requirements of the federal injunction using the unconfined bridge design criteria (structure type is not being recommended by WSDOT Headquarters (HQ) Hydraulics and will be determined by others at future design phases), as described in WDFW's *Water Crossing Design Guidelines* (WCDG; Barnard et al. 2013). This design also meets the requirements of WSDOT's *Hydraulics Manual* (WSDOT 2022a).

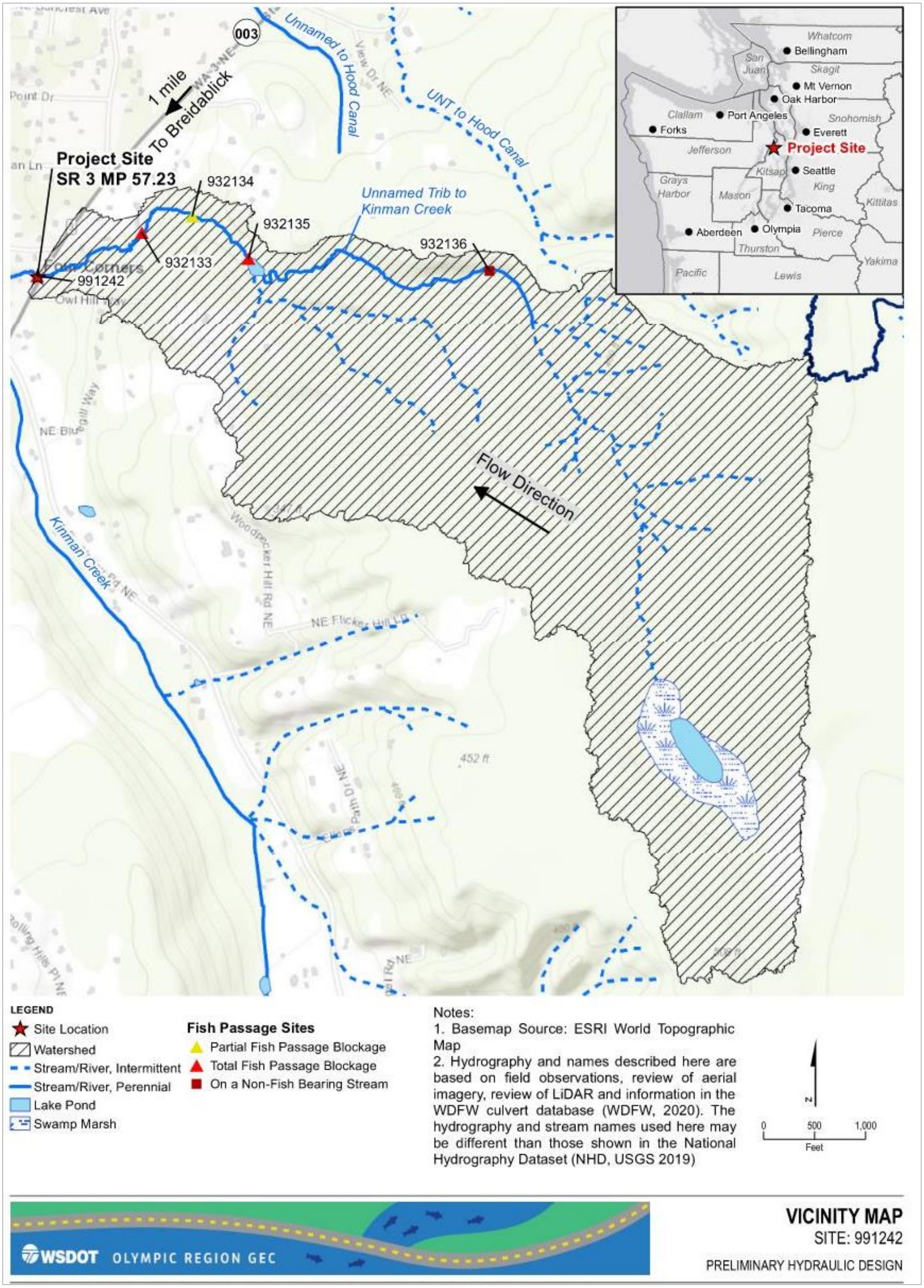


Figure 1: Vicinity map

2 Watershed and Site Assessment

The existing watershed was assessed in terms of land cover, geology, regulatory floodplains, fish presence, site observations, wildlife crossing priority, and geomorphology. This was performed using a site visit and desktop research with resources such as the U.S. Geological Survey (USGS), Federal Emergency Management Agency (FEMA), and WDFW and past records such as observations, maintenance, and fish passage evaluation.

2.1 Site Description

The August 2004 WDFW Level A Culvert Assessment Report found that the existing precast concrete culvert is a full fish barrier due to slope (2.64 percent with an internal grade break) with a 0 percent passability (WDFW 2004). The actual culvert slope was measured at 2.5 percent, per recent WSDOT survey (2021a). According to Figure 3.19 of WDFW's *Fish Passage Inventory, Assessment, and Prioritization Manual* (2019), this crossing is considered a slope barrier due to the lack of embedment and slope greater than 1 percent. This negatively affects fish habitat by limiting the movement of sediment and woody debris. No streambed material was reported in the crossing. The habitat summary report indicates that spawning habitat is fair and rearing habitat is good, with high cover, high spring influence, and some large woody debris (WDFW 2019). WDFW's report deemed this area is a significant reach that could gain 9,375 square feet of spawning habitat, 43,185 square feet of rearing habitat, and a total length of 5,675 feet of potential habitat.

The site is not classified as a Chronic Environmental Deficiency or as a failing structure by WSDOT HQ Hydraulics. Maintenance and emergency repair history for this crossing was requested, but WSDOT indicated there none are for this crossing. The SR 3 crossing outlet is within a special flood hazard area but not within a mapped FEMA floodplain, as shown in Appendix A. The area is designated as Zone A - areas subject to inundation by the 1-percent-annual-chance flood event without base flood elevation (FEMA 2017).

2.2 Watershed and Land Cover

The UNT to Kinman Creek[1] flows from east to west, crossing SR 3 at MP 57.23, joining Kinman Creek approximately 0.15 mile downstream of the SR 3 crossing, and flowing into Hood Canal about 0.4 mile downstream of the SR 3 crossing. The UNT to Kinman Creek does not include any major named tributaries upstream of the SR 3 crossing. A combination of gridded LiDAR topography, desktop hillshade observations (later described in Section 2.3) and field observations by Jacobs Engineering Group Inc. (Jacobs; the design team) were used to define the watershed boundary (Figure 2), resulting in a delineated watershed area of 567 acres (0.9 square mile).[1] Due to the size of the watershed and terrain, the watershed was subdivided into three subwatersheds (991242A, 991242B, and 991242C) based on the terrain and tributaries, with areas encompassing 346 acres, 54 acres, and 166 acres, respectively. The terrain indicates that 991242A and 991242C drain directly to 991242B, ultimately conveyed through the UNT to Kinman Creek, and flow into Hood Canal.

[1] Hydrography and names described herein and shown on Figure 1 are based on field observations, aerial imagery review, LiDAR review, and information in the WDFW culvert database (WDFW n.d.-a). The hydrography and stream names used herein may be different than those shown in the National Hydrography Dataset (USGS 2019).

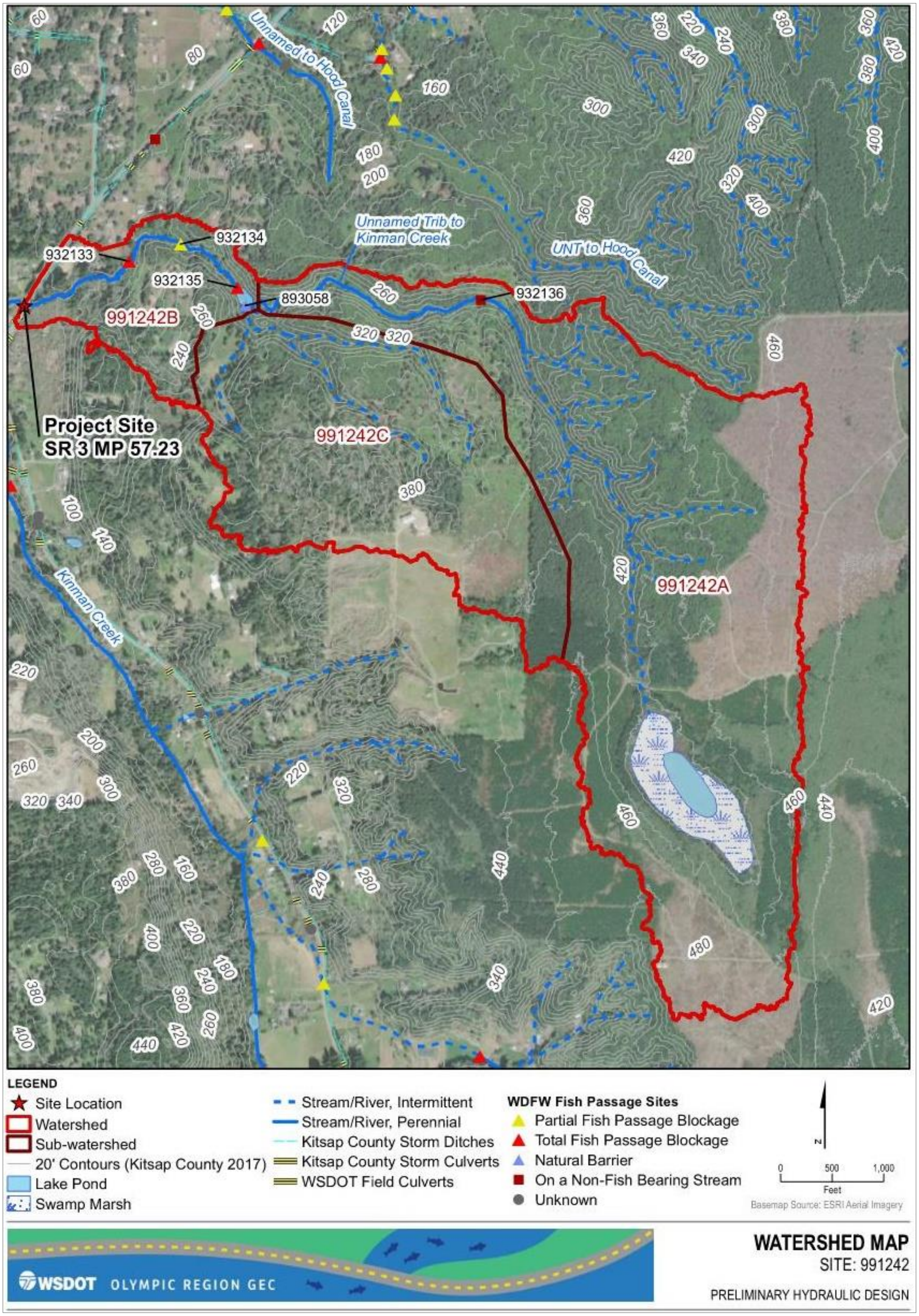


Figure 2: Watershed map

The UNT to Kinman Creek watershed ranges in elevation from 50 to 432 feet using NAVD83 (North American Vertical Datum of 1983) as the vertical datum. The watershed consists of moderately sloped terrain in the eastern portion of the watershed and high-sloped terrain in the western portion of the watershed toward Hood Canal (Figure 3). Land use was evaluated using the National Land Cover Dataset (Multi-Resolution Land Characteristics Consortium [MRLC] 2019a, 2019b), and visual interpretation of aerial imagery (ESRI n.d.). Most of the eastern portion of the watershed is used as forested area with some single-family residences. The land cover is about 59 percent forest (consisting of both evergreen and deciduous forest), 19.9 percent mixed forest, 7.0 perfect shrub/scrub, 5.7 percent woody wetlands, 5.7 percent grassland/herbaceous, and 2.2 percent developed (Figure 4), with the remainder consisting of emergent herbaceous wetlands and pasture/hay, as identified in Table 1. Total impervious area is approximately 0.41 percent of the watershed, based on analysis of the Impervious Dataset within the National Land Cover Dataset (MRLC 2019b). Developed land classes in Table 1 vary in degree of imperviousness and there is not a direct correlation between land cover class and impervious area.

Table 1: Land cover

Land Cover Class	Basin Coverage (Percent)
Deciduous Forest	5.9
Developed, Low Intensity	1.0
Developed, Medium Intensity	0.0
Developed, Open Space	1.2
Emergent Herbaceous Wetlands	0.4
Evergreen Forest	53.1
Grassland/Herbaceous	5.7
Mixed Forest	19.9
Pasture/Hay	0.2
Shrub/Scrub	7.0
Woody Wetlands	5.6

Source: MRLC 2019a.

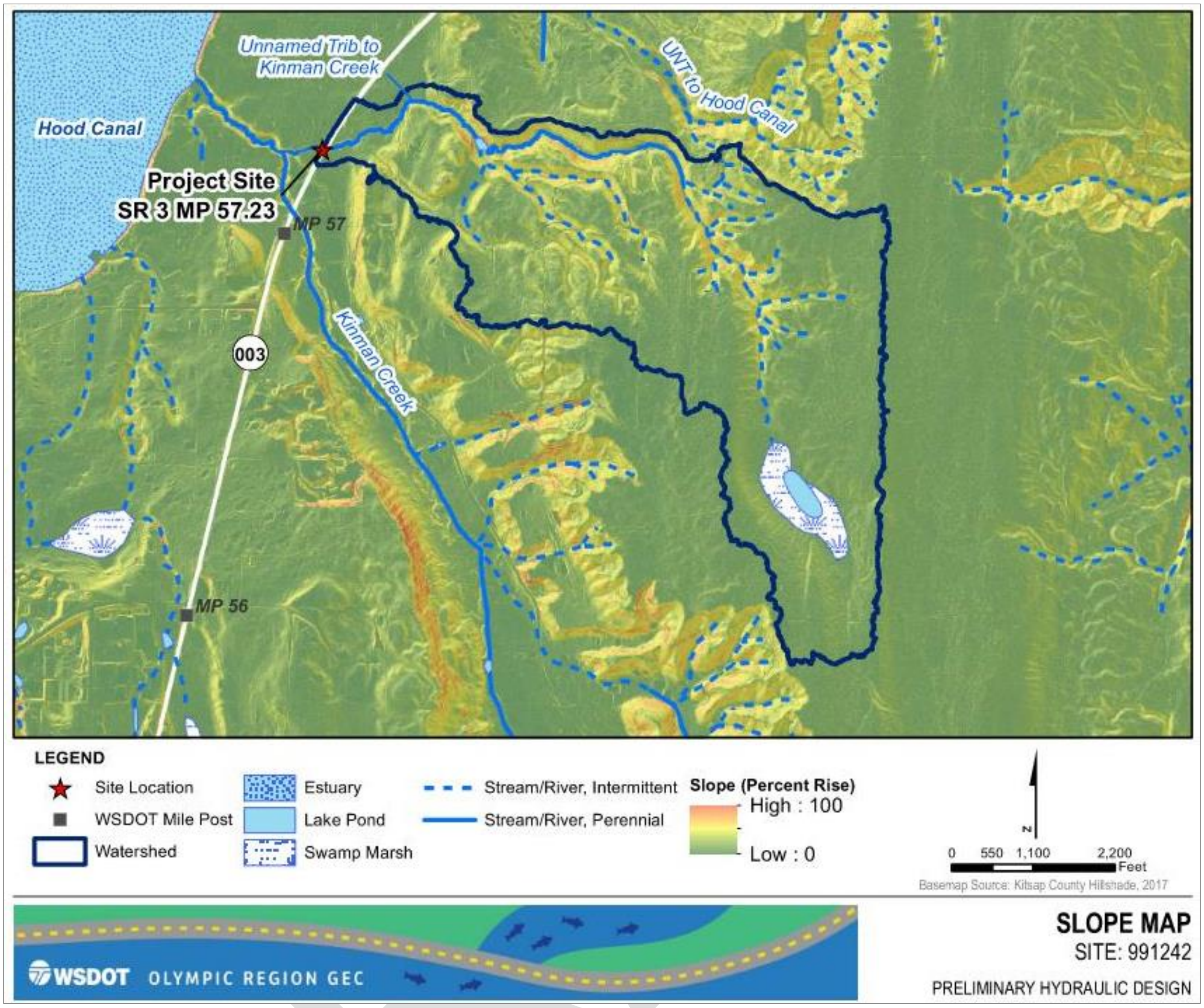


Figure 3: Existing slopes

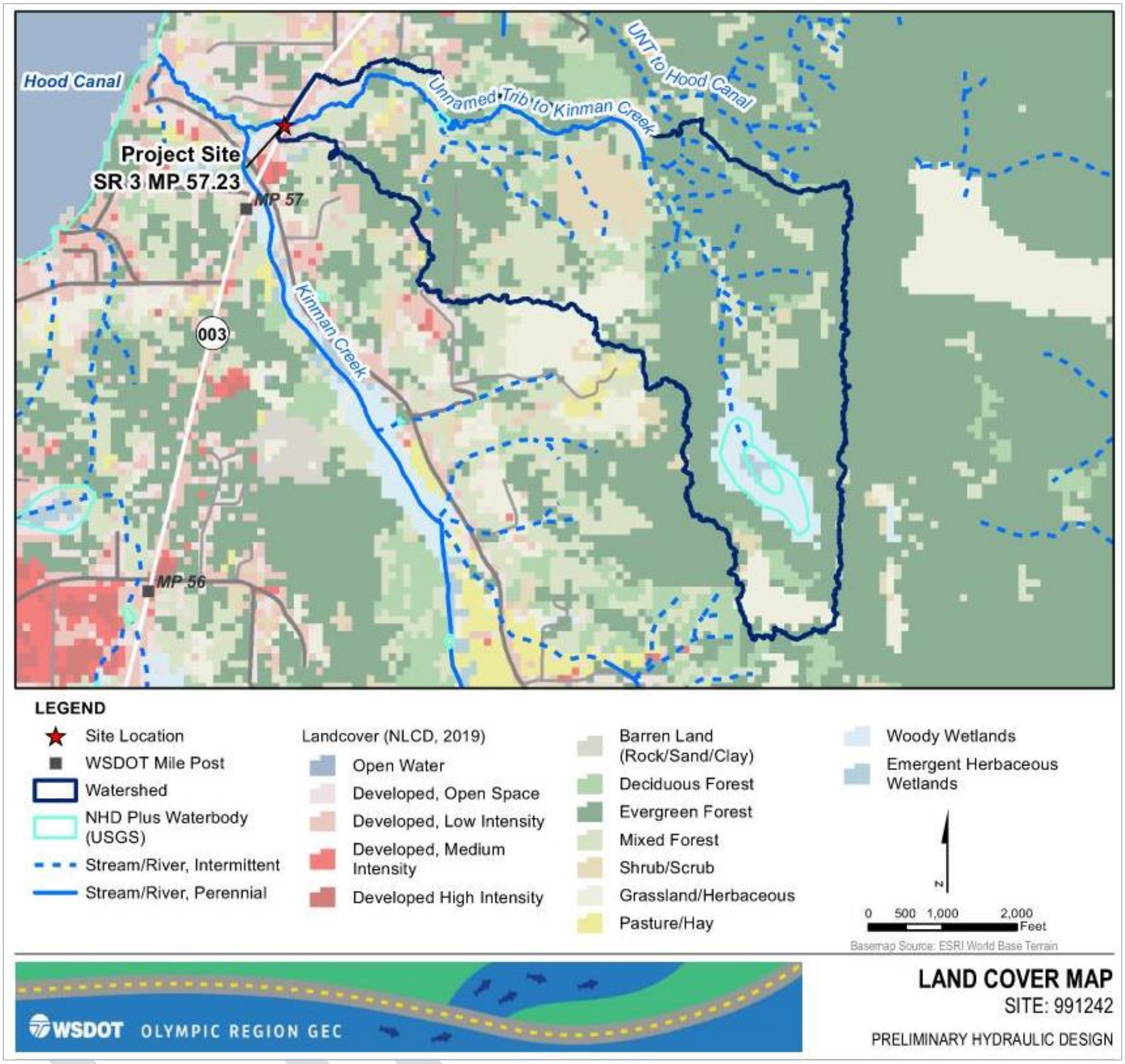


Figure 4: Land cover map (MRLC 2019a)

2.3 Geology and Soils

The UNT to Kinman Creek drains a basin composed of Pleistocene glacial and nonglacial deposits (Figure 5; Natural Resources Conservation Service, U.S. Department of Agriculture [NRCS USDA] 2021). Most of the watershed is Olympia nonglacial deposits (Qco), composed of fluvial and lacustrine material deposited in an ice-free environment. The stream also traverses significant deposits of Possession drift (Qgdp).

Approximately 1,500 feet upstream of the crossing, the channel transitions from a confined valley to unconfined conditions. At this transition, a Pleistocene-era alluvial fan has formed and the stream channel flows across these Vashon alluvial fan deposits (Qgoaf), Vashon recessional outwash (Qgo), and ice contact deposits (Qgic). Vashon alluvial fan deposits dominate the crossing. Fluvially worked deposits, like outwash and fan deposits, tend to be well sorted. The glacial deposits had their source in Pleistocene-era continental glaciation and provide an abundant source of sediment.

A brief examination of aerial photographs did not reveal evidence of recent significant mass-wasting. However, significant scarps are visible in the hillshade imagery on both the northern and southern hillslopes above the channel, roughly 1,500 feet upstream of the crossing (Figure 6). Two of the scarps appear relatively sharp and the slope raster indicates steeper slopes in these areas. These mass-wasting landforms in Possession drift may be contributing significant sediment to the crossing. Reactivation of these mass-wasting features could introduce additional, excess sediment to the channel. No bedrock was observed during Jacobs' fieldwork.

There are a range of soils in the UNT to Kinman Creek basin, primarily from the Rangar, Poulsbo-Ragnar, Indianoloa-Kitsap, and Kapowsin complexes, with the Norma complex dominating in the vicinity of the crossing (NRCS USDA 2021; Figure 7). From upstream to downstream, the dominant soil types along the channel are the Kapowsin gravelly ashy loam, Indianola-Kitsap complex of loamy sand and silt loam, and the Norma fine sandy loam, with Belfast loam dominating from approximately the confluence with Kinman Creek to Hood Canal. Other significant soil units in the basin include the Ragnar fine sandy loam, the Poulsbo gravelly sandy loam and complexes between the two. Apart from the Norma soils in the vicinity of the crossing, soils in the basin are primarily moderately well drained, with pockets of somewhat excessively well-drained soils.

Norma soils are deep and poorly drained, and form along long, narrow stream bottoms from mixed glacial till alluvium. Norma soils are classified as hydric, subject to frequent ponding. Kapowsin soils are moderately well drained formed in glacial till. The Poulsbo-Rangar soils are moderately well drained to well-drained soils formed in glacial till (Poulsbo) and glacial outwash (Rangar). The Indianola-Kitsap complex is a mix of somewhat excessively drained soils formed in sandy glacial outwash (Indianola) and moderately well-drained soils formed in glacial lake sediment (Kitsap). Poorly drained sols may be at higher risk of mass-wasting. Soil types and the underlying geology, along with land use and cover, were used to develop a hydrologic model of the basin, discussed in Section 3.

A boring through the crossing embankment was completed in 2022 (WSDOT 2022b). Boring A-564P-22 contained approximately 12 feet of fill overlying 10 to 12 feet of glacial deposits. The fill material is described as silty sand with gravel and chunks of asphalt. The glacial deposits are well-graded gravel with sand. Both deposits are described as medium dense but cohesionless. Given the nature of these surficial deposits, the risk of lateral migration is moderate, though mitigated by the confined nature of the channel. The risk of long-term degradation is also moderate due to the cohesionless nature of the glacial deposits.

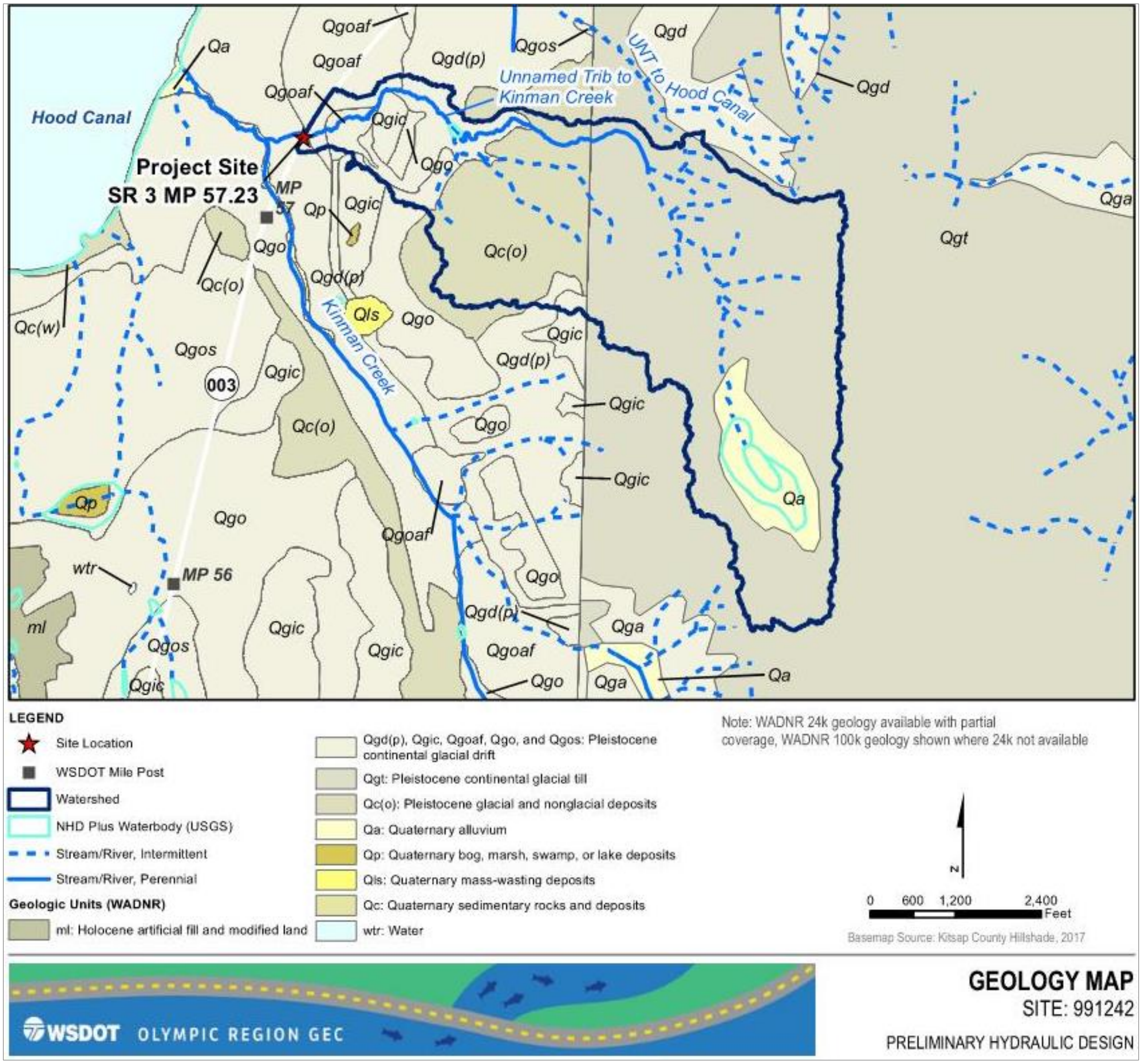


Figure 5: Geologic map

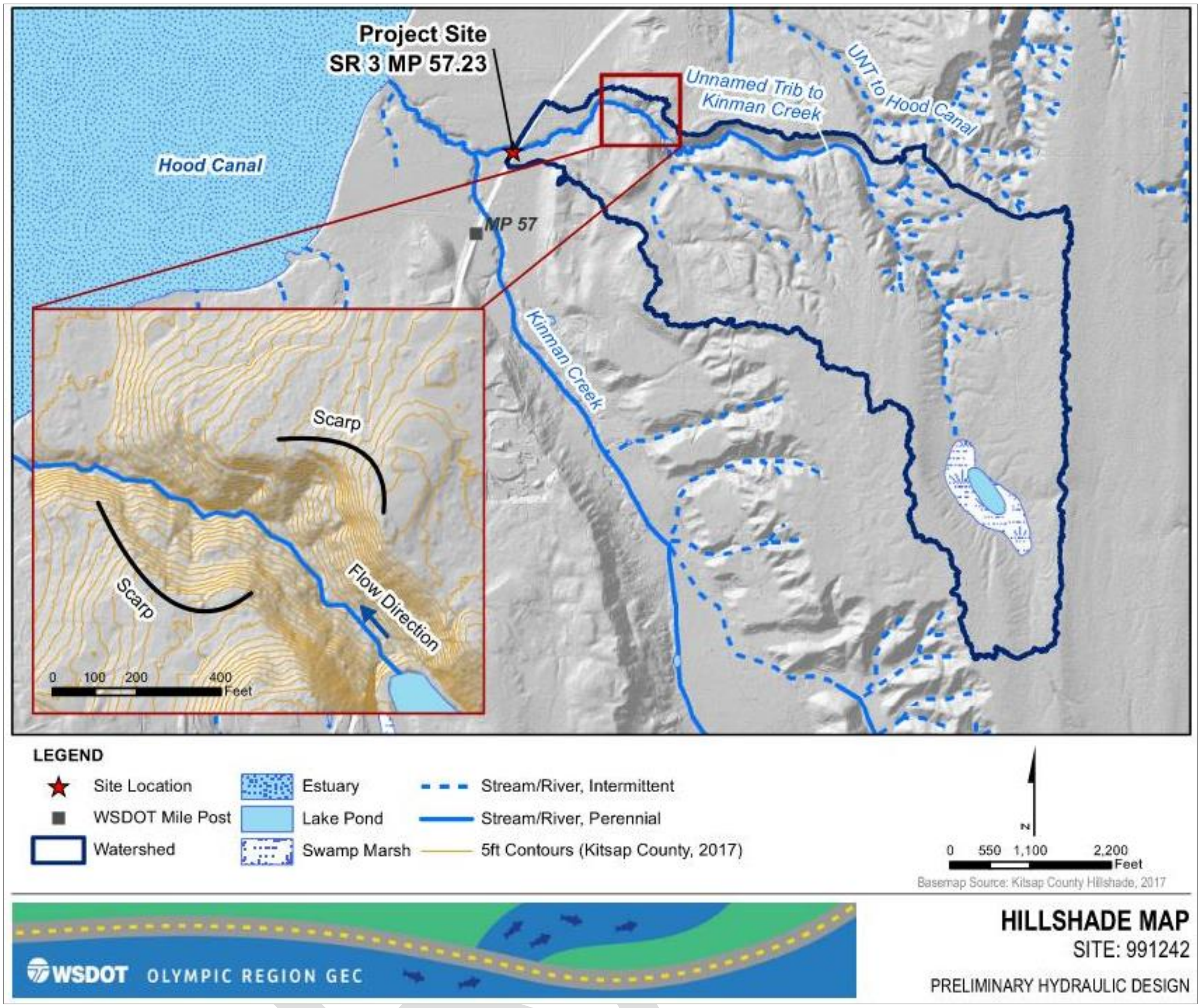


Figure 6: Hillshade map

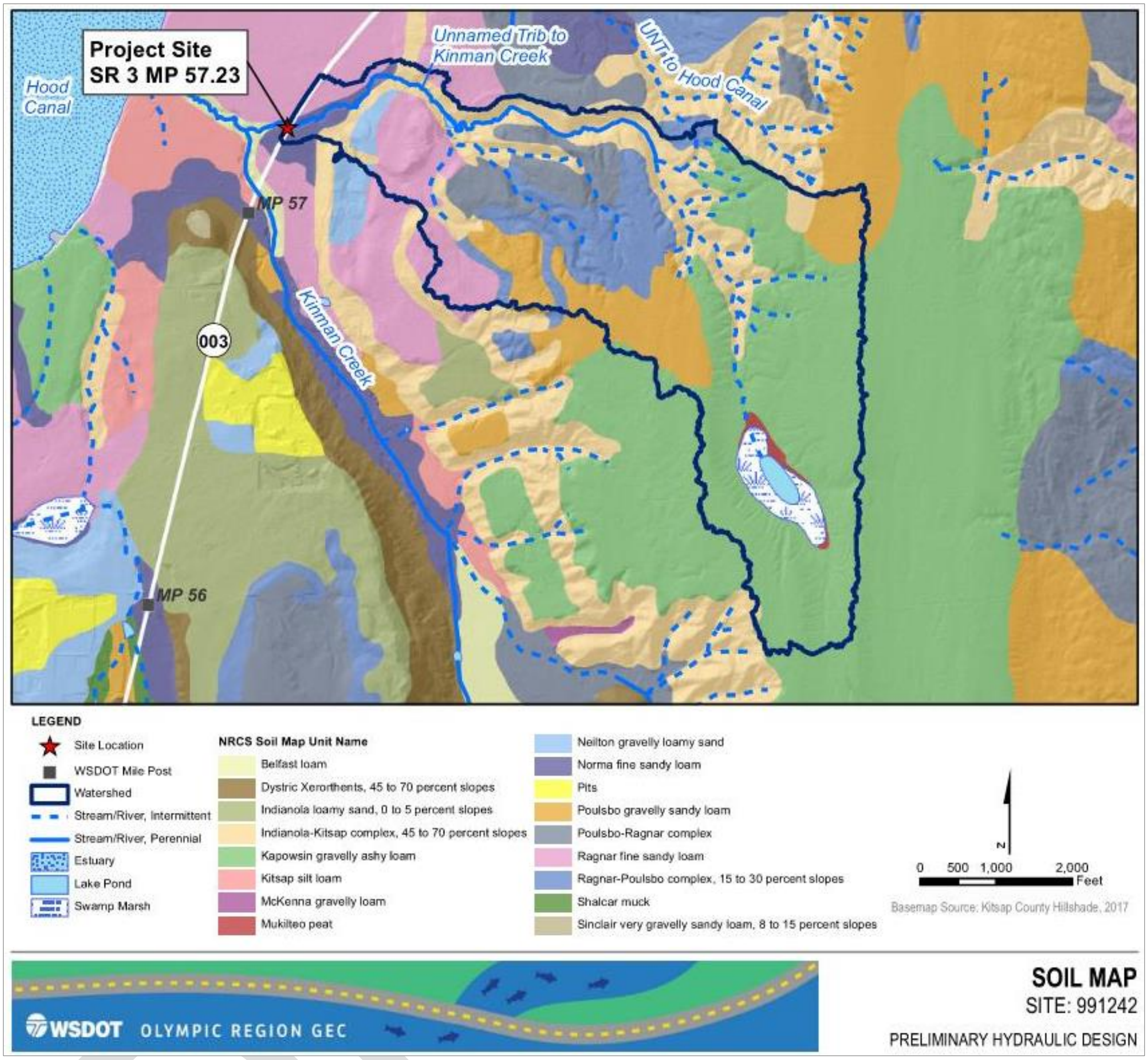


Figure 7: Soils map

2.4 Fish Presence in the Project Area

Jacobs staff reviewed multiple publicly available information sources regarding historic and current fisheries resources and distribution within the project area, including the following:

- WDFW Fish Passage and Diversion Screening Inventory (n.d.-b), which includes a compilation of barrier and habitat assessment reports
- WDFW Fish Passage and Diversion Screening Inventory Database, Level A Culvert Assessment Report for the UNT to Kinman Creek (2004)
- Statewide Washington Integrated Fish Distribution (SWIFD) database (Northwest Indian Fisheries Commission [NWIFC] n.d.)
- Ecology Watershed Restoration and Enhancement Draft Plan, WRIA 15 Kitsap Watershed (2021)
- National Marine Fisheries Service Essential Fish Habitat Mapper (n.d.)
- WDFW APPS Hydraulic Project Approval database search by Section/Township/Range (n.d.-c; No projects within the vicinity)
- Washington State Recreation and Conservation Office project database search by WRIA (Ecology n.d.; No projects within the vicinity)
- Site observations by a Jacobs biologist on December 1, 2021

Jacobs representatives, including a fisheries biologist, conducted a site visit on December 1, 2021, to document the existing conditions of the channel upstream and downstream of the crossing. The National Hydrography Dataset documents the UNT to Kinman Creek as a perennially flowing stream (USGS 2019). Field indications support the determination of a perennially flowing waterbody, including a well-defined channel, clean sand and gravel substrate, and lack of vegetation below ordinary high water. Streams with a channel width greater than 2 feet and a contributing basin larger than 50 acres in Western Washington are presumed to have fish use (WAC 22-16-131). Streams with existing or historic fish use within this region are mapped as Essential Fish Habitat for Pacific salmon under the Magnuson-Stevens Fishery Conservation and Management Act; therefore, the UNT to Kinman Creek is listed as Essential Fish Habitat for Pacific salmon. The UNT to Kinman Creek is not listed as designated critical habitat for aquatic species under the federal Endangered Species Act.

The UNT to Kinman Creek has the potential to support native resident and anadromous fish species both upstream and downstream of the existing crossing; however, the size of the stream may indicate that it primarily supports resident and sea-run cutthroat trout (*Oncorhynchus clarkii*) and other resident aquatic species, though coho (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) may also utilize the UNT to Kinman Creek for spawning and rearing. Chum (*Oncorhynchus keta*), Chinook (*Oncorhynchus tshawytscha*), pink (*Oncorhynchus gorbuscha*), sockeye (*Oncorhynchus nerka*), and bull trout (*Salvelinus confluentus)* were not documented to occur or modeled as potentially occurring in the UNT to Kinman Creek by WDFW (2004).

Section 2.6.3 discusses fish habitat suitability in greater detail, including fish utilization by life stages. Table 2 summarizes aquatic species that are documented to occur within the project area based on this data review.

Table 2: Native fish species potentially present within the project area

Species	Presence (presumed, modeled, or documented)	Data source	ESA listing
Puget Sound Steelhead (*O. mykiss)*	Modeled- Gradient Accessible Potential	SWIFD Web App WDFW Fish Passage Report	Threatened, National Marine Fisheries Service
Coho Salmon (*O. kisutch*)	Modeled- Gradient Accessible Potential	SWIFD Web App WDFW Fish Passage Report	Not Listed
Cutthroat Trout (Sea Run) (*O. clarkii clarkia*)	Modeled- Gradient Accessible Potential	SWIFD Web App WDFW Fish Passage Report	Not Listed
Cutthroat Trout (Resident) (*O. clarkii clarkia*)	Modeled- Gradient Accessible Potential	SWIFD Web App WDFW Fish Passage Report	Not Listed

Sources: NWIFC n.d.; WDFW 2004.

2.5 Wildlife Connectivity

The 1-mile-long segment that UNT to Kinman Creek falls in is not ranked for Ecological Stewardship and is low priority for Wildlife-related Safety by WSDOT HQ ESO. Adjacent segments to the north and south are ranked low. A wildlife connectivity memorandum will not be provided at this site and additional width or height has not been recommended by WSDOT HQ ESO for wildlife connectivity purposes.

2.6 Site Assessment

2.6.1 Data Collection

On December 1, 2021, Jacobs staff investigated approximately 200 feet upstream of the culvert inlet and 200 feet downstream of the culvert outlet. A total of four pebble counts, all completed upstream, were performed.

The reference reach and bankfull width (BFW) concurrence site visit with WDFW and the Tribes occurred on January 21, 2022. The group agreed that it was reasonable to have a BFW of 6 to 7 feet for the proposed design based on the reference reach, discussed in further detail in Section 2.7.1.

Figure 8 shows the locations of all BFW measurements, pebble counts, and the reference reach. Further detail on sediment is explained in Section 2.7.3. Six BFW measurements were collected and are explained in further detail in Section 2.72. Field reports for the December 1 and January 21 site visits are provided in Appendix B.

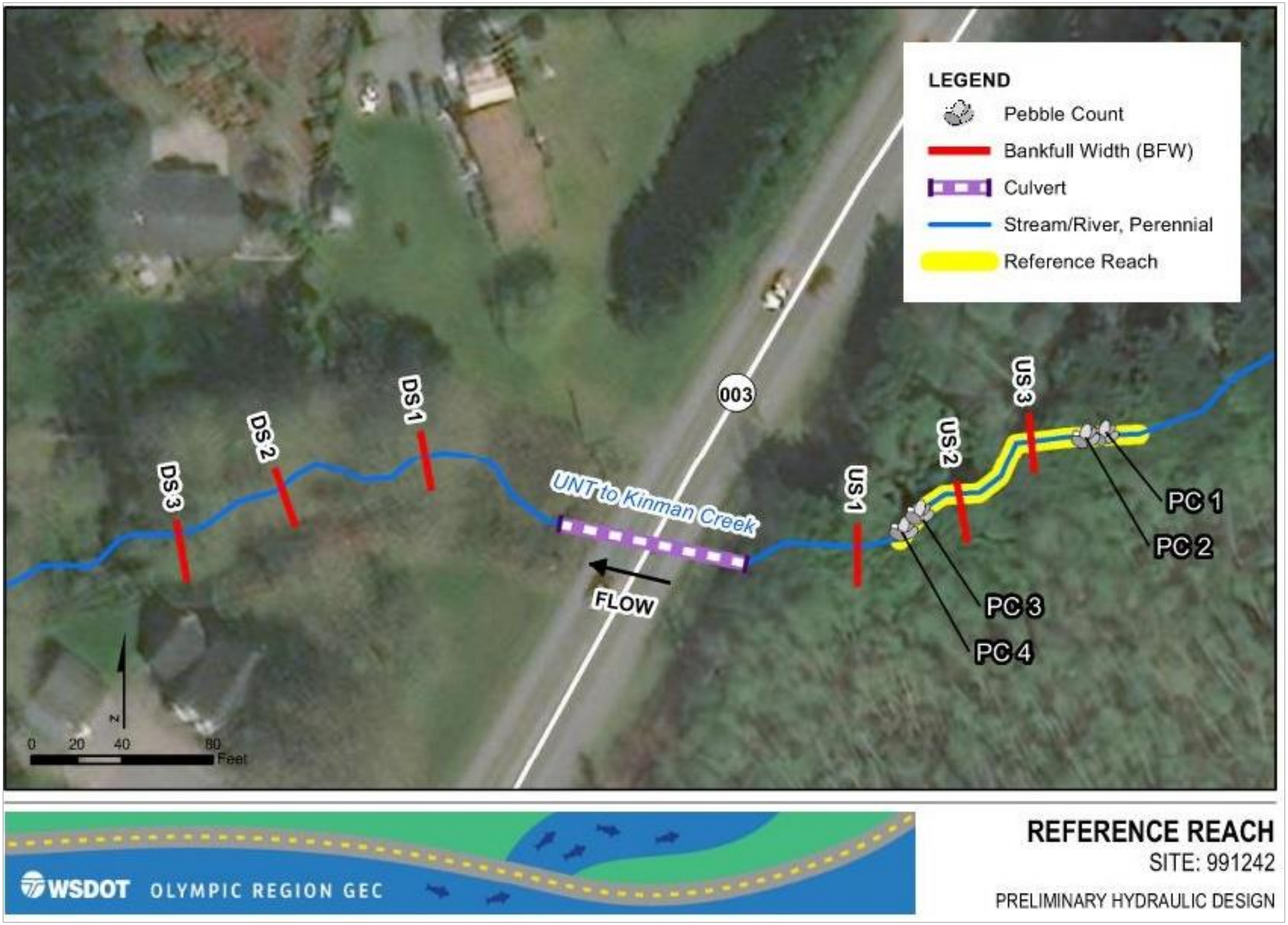


Figure 8: Reference reach, bankfull width, and pebble count locations

2.6.2 Existing Conditions

The existing crossing consists of a 36-inch-diameter, 84-foot-long, precast concrete culvert that runs west to east at a 7 degree skew to the highway with an overall gradient of 2.5 percent. There is approximately 10 to 15 feet between the culvert crown and the road surface. The culvert appears intact but the inlet and outlet are partially obstructed by Himalayan blackberry. The nearest infrastructure noted in the vicinity of the crossing is the surrounding properties downstream of the existing crossing, particularly the building on the left bank, which will be a consideration in the proposed grading. As-builts of SR 3 were obtained from WSDOT HQ Hydraulics and no information pertinent to the UNT to Kinman Creek culvert was observed.

Downstream of the crossing, the channel is incised 4 to 5 feet, with sandy banks and bed overgrown with non-native, invasive vegetation, predominantly Himalayan blackberry (Figure 9). The incision lessens downstream, and an overstory of deciduous trees begins approximately 75 feet downstream of the culvert outlet, but the blackberry and sandy banks and bed persist through the area observed in the field. Within the area investigated, no historic floodplain was observed.

Upstream of the crossing, the first approximately 60 feet of channel roughly parallels the road prism before turning east into a more forested area, where the reference reach begins. Near the crossing, the channel is incised 1 to 3 feet. Farther upstream, the channel shows less sign of incision. Channel incision and stability is discussed in more detail in section 2.7.4. Channel types are dominated by wood-forced pools and glides separated by short riffles. Large woody material (LWM) was rare in the upstream reach, but live root and accumulations of smaller organic material formed steps (Figure 10). The incised nature of much of the channel limits floodplain development and access, but floodplain interaction was observed where gravel and sand were deposited. No flow splits or floodplain channels were noted. However, discontinuous flow paths resembling swales were observed.

With the exception of the vegetation clearing performed to facilitate the site survey, no obvious signs of maintenance were noted. As noted in Section 2.1, the culvert crossing is considered a slope barrier due to the lack of embedment and slope greater than 1 percent; the lack of streambed material in the crossing means a lack of habitat.

Figure 9: Downstream reach with incision

Figure 10: Upstream segment. Roots and other material form steps and pools with gravel tailouts

2.6.3 *Fish Habitat Character and Quality*

Instream habitat conditions within the upstream reach of the project area consists of a pool-glide to glide habitat type, with pools created by smaller legacy coniferous LWM and living riparian tree roots. Pools were intermittent and ranged in depth from 6 inches to 1.5 feet. Instream habitat conditions in the downstream reach consists of glide habitat type within a confined and straightened channel with no wood present, resulting in poor in-channel complexity. Instream substrate within both reaches consists primarily of small gravels with a high percentage of coarse and fine sand (Figure 11). Additional information on sediment is provided in Section 2.7.3. Streambed gravels were clean and free from algae or moss, which indicates cold stream temperatures and perennial flow. There were no field indications of significant floodplain wetlands as evidenced by a lack of a floodplain bench or wetland vegetation in either the upstream or downstream reach.

The stream width, depth, gradient, and substrate is suitable for rearing, migration, and spawning of resident and sea-run cutthroat trout and is modeled as suitable for migration and spawning of steelhead and coho; however, the stream size and water depth may be a limiting factor for a significant run of steelhead and coho. Suitable rearing habitat for all resident and anadromous juvenile fish is present throughout the upstream reach. Rearing habitat within the downstream reach is limited due to the lack of cover and channel complexity. Information on riparian conditions is provided in Section 2.6.4.

Figure 11: Upstream reach, typical channel cross section, and smaller gravel/sand substrate

2.6.4 Riparian Conditions, Large Wood, and Other Habitat Features

Riparian vegetation within the upstream reach consists predominantly of a mature, closed-canopy coniferous forested stand greater than 150 feet in width on both sides of the stream (Figure 12). The overstory is dominated by mature Western red cedar (*Thuja plicata*) and red alder (*Alnus rubra*) with an open understory of salmonberry (*Rubus spectabilis*), red huckleberry (*Vaccinium parvofolium*), and sword fern (*Polystichum munitum*). Riparian vegetation within the downstream reach is primarily non-native blackberry thickets (*Rubus* sp.) and red alder, surrounded by lawn and residential structures within 20 to 50 feet of the stream (Figure 13).

The majority of the instream coniferous LWM is legacy wood (woody material present in the stream prior to widespread logging in the early twentieth century). Removing the majority of mature conifers eliminated a generation of coniferous LWM recruitment potential. The existing canopy consists of mature primarily coniferous tree species ranging from 18 to 24 inch diameter at breast height; however, these trees are of similar age (consistent with post early-twentieth century regrowth) but are not expected to serve as significant LWM recruitment potential for many decades.

Within the upstream reach, existing instream LWM is a mix of legacy coniferous wood, living tree roots, and recently downed deciduous material but is generally smaller in size compared to the average diameter at breast height of the surrounding riparian trees and limited in distribution. Where LWM occurs, it is associated with lateral and thalweg scour pools and step pools 2 to 5 times the depth of the glide sections of the stream, providing important refugia and cover for aquatic species including salmonids (Figure 14). Absent of other geologic features, such as boulders or exposed bedrock, LMW and living tree roots are the primary habitat-forming features in the surveyed area. There was no LWM noted in the downstream reach within the extent of survey. Presence of LWM and corresponding pools for salmonid refugia and cover in the upstream reach is moderate and absent within the downstream reach. No evidence of beaver activity was noted.

Figure 12: Upstream reach, coniferous overstory with a mix of mid- to late-successional native riparian species and an open understory common to a closed-canopy overstory

Figure 13: Downstream reach, facing downstream, noting dominance of blackberries and limited deciduous tree canopy

Figure 14: Recent LWM recruitment resulting in pool habitat complexity

2.7 Geomorphology

Geomorphic information provided for this site includes selection of a reference reach, geometry and cross sections of the channel, and stability of the channel both vertically and laterally of the UNT to Kinman Creek.

2.7.1 Reference Reach Selection

To help inform new channel design, a reference reach was identified during the site visit on December 1, 2021. The identified reference reach is located approximately 150 feet upstream of the culvert and extends for another 100 feet upstream in a forested area to the east of the crossing (Figure 8). In this reach, the channel has well-developed sequences of long (10 to 15 feet) glides and short (10 feet or less) riffles separated by short, forced step-pools. The approximate distribution of channel types is 35 percent forced pools, 10 percent riffles, and 55 percent glide. Forced pools are created by live tree roots and accumulations of small woody material. Compared to downstream of the outlet, the reference reach does not show signs of incision. Tree roots and wood accumulations in the channel appear to hold the grade of the reference reach, enhancing its vertical stability.

The channel type of the reference reach may be considered a step-pool unit with a tread (Church and Zimmerman 2007), where the tread is defined as the end of the pool and the crest of the next step. The extended tread is exhibited in runs, glides, and riffles. This channel type can occur in flatter gradient reaches. The overall reference reach slope is 1.6 percent.

Banks are generally about a foot high, and vertical in some locations but cohesive and stable with mature vegetation consisting of a cedar canopy with sword fern undergrowth (Figure 15). No flow splits or floodplain channels were noted. The channel appears to be relatively undisturbed in recent years, though stumps with buckboard notches in the vicinity indicate that the area was logged historically. This was deemed the most appropriate reference reach due to its comparable slope and stable, repeating sequences of riffle, runs, and glides separated by short riffles and forced step-pools. This reach has moderate floodplain connection, evidenced by periodic floodplain deposition of sands and small gravels and intact native riparian vegetation. The alignment of the reference reach is unmodified, except by occasional LWM, and exhibits sediment continuity (neither excess deposition or erosion) (Figure 16). The periodic steps enable lower-gradient reaches (glides and runs) and retention of finer (gravel and finer) bed materials than would otherwise be expected in a reach of this slope (Figure 17). A typical channel segment in the reference reach showing the typical BFW and a forced run is shown on Figure 18. BFW measurements and pebble counts were taken and are further described in Sections 2.7.2 and 2.7.3, respectively.

The reach downstream of the culvert was not considered a suitable reference reach due to the markedly greater incision (4 to 5 feet); the dominance of non-native, invasive vegetation; and a straightened planform (Figure 9). The roots of the non-native blackberry in the sandy soils at the site produce a steep-sided channel that likely does not represent the natural morphology at the site. Similarly, the channel reach (approximately 60 to 100 feet) immediately upstream of the inlet was rejected due to its straightened planform (parallel to the roadway), simplified channel geometry, and influence of the existing crossing.

Figure 15: Reference reach, looking upstream

Figure 16: Step formed by organic and small woody material

Figure 17: Glide channel type in reference reach with sand and small gravel bed material.

Figure 18: Typical forced glide with woody material step in the reference reach.

2.7.2 Channel Geometry

The channel planform is meandering, with a sinuosity of roughly 1.05 to 1.10. Meandering is limited by incision into the alluvial fan surface and outwash surface. The channel geometry is varied from upstream to downstream of the crossing. Channel geometry is typically trapezoidal, with steep, cohesive banks. Lower slope reaches, such as glides, exhibit in-channel lateral sandy deposits adjacent to the thalweg. Bank heights vary from 1.0 to 1.5 feet upstream of the crossing and greater than 1.5 feet downstream of the crossing. Banks are composed of sandy and silty cohesive material that allows steep, stable banks.

Active floodplain was observed throughout the reach upstream of the crossing, except for the first 60 feet upstream of the inlet. In this reach, the inlet acts as a base level control, steepening the channel immediately upstream. However, this effect does not propagate upstream. Recent sediment deposition was observed in the reference reach. Floodplain width varied from 20 to 40 feet. Downstream of the crossing, floodplain was not easily discerned due to pervasive blackberry and substantial incision of the channel, limiting floodplain engagement. BFW measurements were taken in the upstream and downstream reaches (including within the reference reach). The BFW measurement locations listed in Table 3 are shown on Figure 8. BFWs were measured at 4.0 to 6.0 feet in the upstream reference reach (Figure 19 and Figure 20) and 6.0 to 6.9 feet in the downstream reach. A design BFW of 6 feet, based on the field measurements taken in the reference reach, was agreed to by the comanagers during the concurrence site visit. However, materials will allow the channel to increase width over time. As previously mentioned, the slope of the reference reach is approximately 1.6 percent; additional information regarding slope ratio is in Section 4.1.3. The selected design slope should facilitate uniform flow conditions without sharp transitions in energy grade slope. Consideration of the minimum hydraulic width is also driven by the selection of design slope.

Table 3: Bankfull width measurements

BFW number	Width (ft)	Included in design average?	Location measured (STA)	Concurrence notes
US 3	4.0	No	Existing STA 14+82	Comanagers concurred on 01/21/2022
US 2	6.0	Yes	Existing STA 14+15	Comanagers concurred on 01/21/2022
US 1	6.0	Yes	Existing STA 13+41	Comanagers concurred on 01/21/2022
DS 1	6.0	No	Existing STA 11+26	Comanagers concurred on 01/21/2022
DS 2	6.9	No	Existing STA 10+63	Comanagers concurred on 01/21/2022
DS 3	6.0	No	Existing STA 10+10	Comanagers concurred on 01/21/2022
Design average	6.0	N/A	N/A	Comanagers concurred with a design BFW of 6 feet on 01/21/2022

Figure 19: Location of BFW US 2 in reference reach (looking downstream).

Figure 20: Location of BFW US 3 in reference reach (looking downstream).

Width-to-depth (W/D) ratio is a metric that indicates the channel shape. A large W/D ratio (>12 per Rosgen 1994) indicates a wide, shallow channel; a small W/D ratio indicates a narrow, deep channel. Given the BFW measurements shown in Table 3 and measured bankfull depths of 1 to 2 feet, all observed reaches of the UNT to Kinman Creek channel have low (3 to 5) W/D ratios, as illustrated on Figure 21. This channel shape will serve as a guide in development of the design channel. Figure 21 helps illustrate how the floodplain in the upstream reach is more likely accessed than the downstream reach.

Applying the Cluer and Thorne (2013) model of channel evolution (Figure 22) to the UNT to Kinman Creek crossing shows the channel in different channel evolutionary stages. The reference reach most closely approximates Stage 1 ("sinuous"), where the channel is dynamic yet stable within a floodplain. The reference reach (and the rest of the upstream channel investigated at the second site visit on December 1, 2021) has incised into a fan surface and has established an active floodplain. This process reflects loss of fan-building sediments, as much of the channel disturbance is from historic logging. Downstream of the crossing, the channel is in Stage 2 ("channelized"), reflecting the more recent acute disturbance associated with site development of the adjacent houses and businesses.

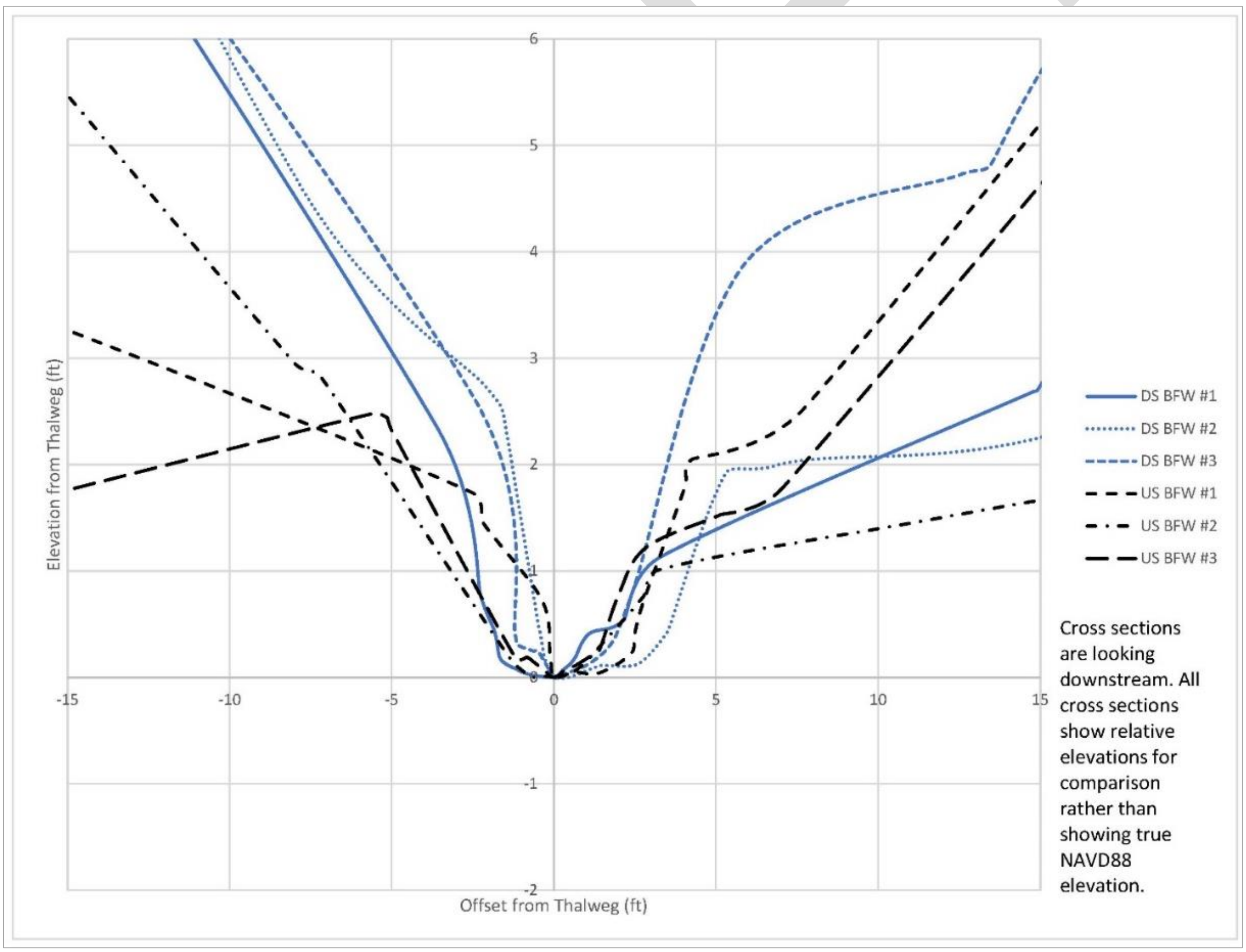


Figure 21: Existing cross section examples

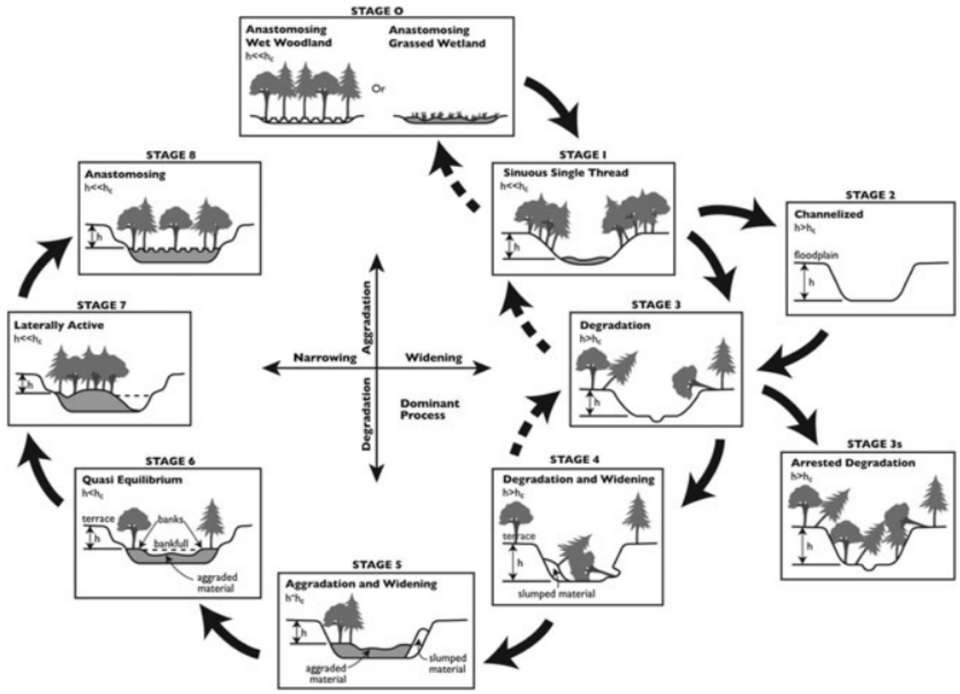


Figure 4. Stream Evolution Model based on combining the Channel Evolution Models in Figures 1–3, inserting a precursor stage to better represent pre-disturbance conditions, adding two successor stages to cover late-stage evolution and representing incised channel evolution as a cyclical rather than a linear phenomenon. Dashed arrows indicate 'short-circuits' in the normal progression, indicating for example that a Stage 0 stream can evolve to Stage 1 and recover to Stage 0, a Stage 4-3-4 short-circuit, which occurs when multiple head cuts migrate through a reach and which may be particularly destructive. Arrows outside the circle represent 'dead end' stages, constructed and maintained (2) and arrested (3s) where an erosion-resistant layer in the local lithology stabilizes incised channel banks

Figure 22:Stream evolution model (Cluer and Thorne 2013)

2.7.2.1 Floodplain Utilization Ratio

The floodplain utilization ratio (FUR) is defined as the flood-prone width (FPW) divided by the BFW. The FUR was calculated using the agreed upon design BFW of 6 feet along with measurements from an existing-conditions hydraulic model produced in the Bureau of Reclamation's Sedimentation and River Hydraulics – Two Dimension (SRH-2D) Version 3.3.1 computer program, a two-dimensional (2D) hydraulic and sediment transport numerical model (2020). A ratio under 3.0 is considered a confined channel and above 3.0 is considered an unconfined channel.

The 100-year flood was simulated and used to measure the FPW. However, modifications were made to the existing-conditions culvert defined using the HY-8 Culvert Analysis Program (HY-8; Federal Highway Administration 2021) to remove the backwater effect produced by the existing undersized culvert. This model simulation does not meet the requirements of a natural-conditions model. Eight FPW measurements were made to determine the FUR along the reach (Figure 23). These measurements were made at locations where bankfull measurements were made, as well as the upstream and downstream extents of the reference reach. Table 4 shows the FPW measurement and the calculated FUR at each location. Upstream of the existing crossing, the highest calculated FUR in the upstream reach was 4.6 and the lowest was 3.0, meaning the channel was unconfined. Downstream of the crossing, the stream is more incised and was fully confined with the highest FUR calculated at 1.5 and the lowest calculated at 1.1. The overall average of the FWP equaled 20.2 feet with a resulting FUR of 3.6.

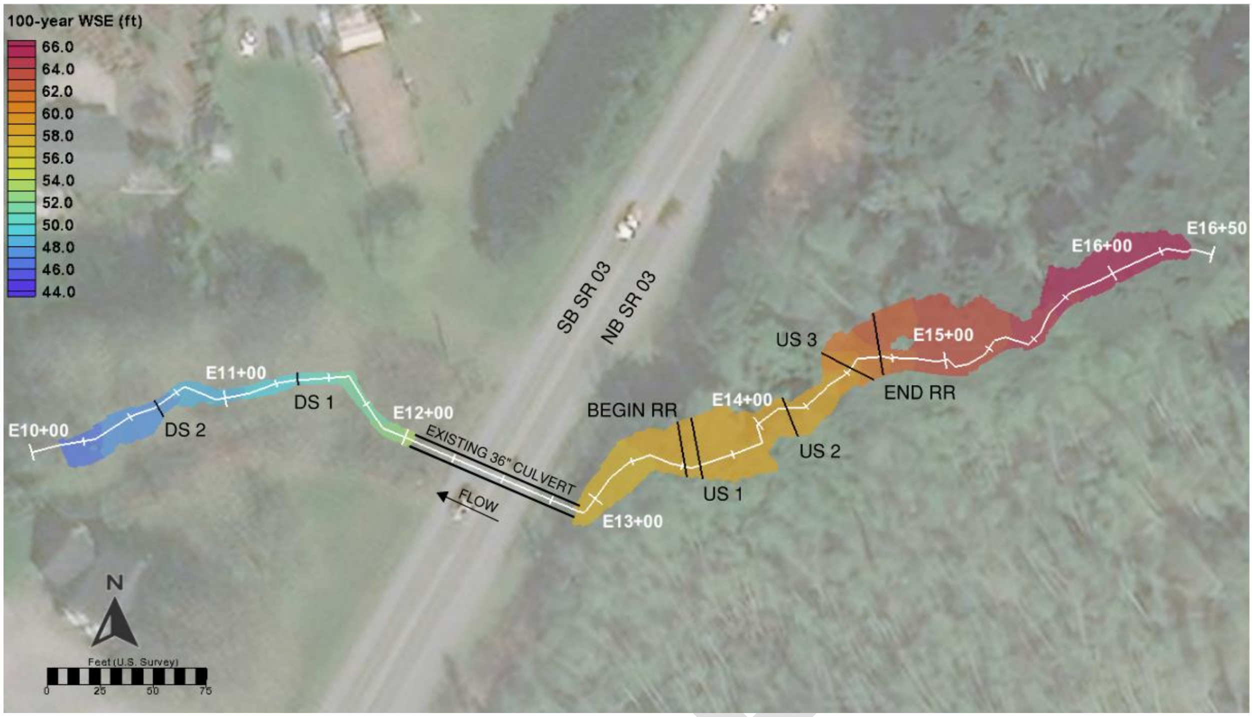


Figure 23: FUR locations

Table 4: FUR determination

Measurement Location	FPW (ft)	FUR	Confined/ Unconfined	Included in average FUR determination
End Reference Reach	27.8	4.6	Unconfined	Yes
US 3	25.8	4.3	Unconfined	Yes
US 2	17.7	3.0	Unconfined	Yes
US 1	24.6	4.1	Unconfined	Yes
Start Reference Reach	18.8	3.1	Unconfined	Yes
DS 1	6.5	1.1	Confined	No
DS 2	8.9	1.5	Confined	No
Average	20.2	3.7	Unconfined	N/A

2.7.3 Sediment

The channel bed material upstream and downstream of the crossing was characterized by a Wolman pebble count (upstream) and by visual assessment (downstream). Downstream of the crossing, the bed was nearly all sand with no viable locations for pebble counts. Upstream of the crossing, in the reference reach, four pebble counts were taken. (Figure 8). Due to the small channel width, all pebble counts were modified, meaning that each count consisted of 30 measurements. Two pebble counts were taken in riffles and two pebble counts were taken in glides. Upstream of the crossing, streambed material (Figure 24) in the glide reaches is dominated by sand and silt (D_{50} <0.04 inch), and riffles are dominated by small gravel (D_{50} of 0.2 inch).

No boulders were noted in the stream; however, a 10-inch cobble was sampled in one of the glide reaches. This clast does not appear to be part of the typical incoming sediment supply to the channel and may be exhumed from the Vashon alluvial fan or outwash deposit.

The average median grain sizes (D_{50}) are 0.04 inch and 0.4 inch in glides and riffles, respectively (Table 5). Sediment size cumulative distributions for all modified pebble counts (Figure 25) show that glides are significantly finer than riffles. Median grain size in glides is approximately fine sand (roughly 0.02 to 0.4 inch) versus small gravel (roughly 0.10 to 0.25 inch) in riffles. All pebble counts show a significant mode in sand and finer (Figure 26).

Figure 24: Typical upstream sediment

Table 5: Sediment properties near the project crossing

Particle size	Pebble Count 1, Glide diameter (in)	Pebble Count 2, Riffle diameter (in)	Pebble Count 3, Glide diameter (in)	Pebble Count 4, Riffle diameter (in)	Average diameter for Glides (in)	Average diameter for Riffles (in)
Included in average?	Yes	Yes	Yes	Yes	N/A	N/A
$\mathbf{D_{16}}$	0.03	0.2	<0.00	0.04	0.02	0.1
$\mathbf{D_{50}}$	0.04	0.6	0.03	0.2	0.04	0.4
$\mathbf{D_{84}}$	0.2	2.1	0.4	0.5	0.3	1.3
$\mathbf{D_{95}}$	1.1	3.4	0.8	0.7	1.0	2.1
$\mathbf{D_{100}}$	10.1	5.0	0.9	0.9	5.5	3.0

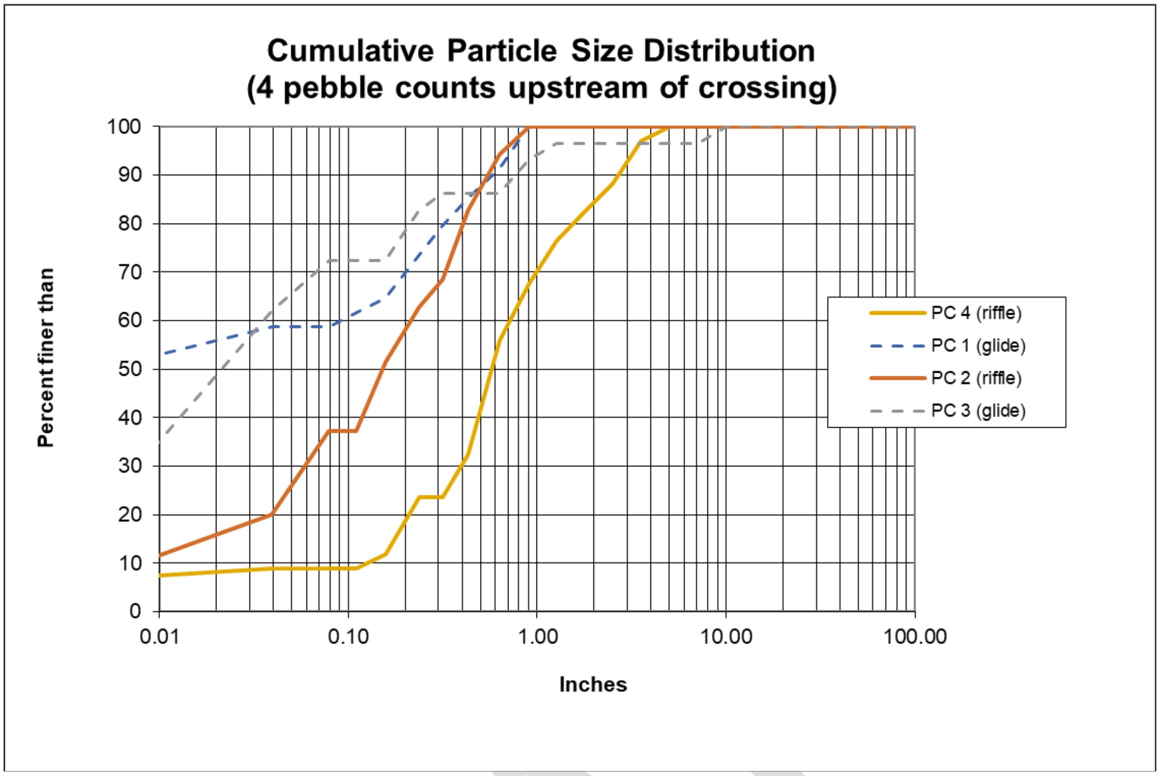


Figure 25: Sediment size cumulative distributions

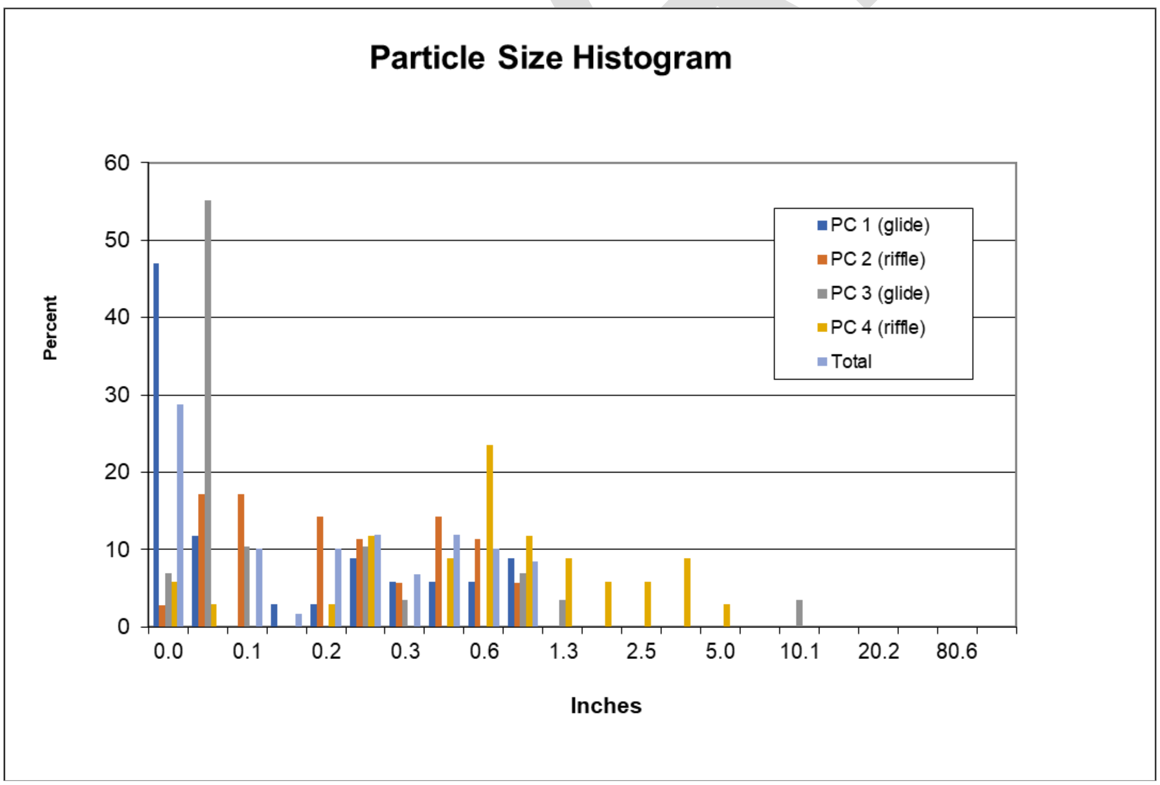


Figure 26: Sediment size histograms

2.7.4 Vertical Channel Stability

The vertical stability of the channel was assessed using the longitudinal profile (Figure 27) evaluation of upstream mass-wasting, and field indicators. The longitudinal profile is straight (neither convex nor concave) with the profile slope generally between 3 to 5 percent. At the reach scale, the overall shape of the profile is straight, but it exhibits steps (Appendix C). The steps in the profile enable lower-gradient channel types, such as glides, to persist by slowing flow behind small accumulations of wood that function as steps. These steps act as minor grade control structures. Longevity of these steps is relatively short, but there are sufficient steps to hold the overall grade and likely sufficient recruitment of woody material to reform steps.

The steps in the profile also allow for finer grain sediments to persist in the channel than would otherwise be present at these gradients. Within the reference reach, extensive dunefields were observed. In other parts of the reference reach, the bed material is matrix-supported, meaning that gravel clasts are commonly not in contact with other gravel clasts and are separated by sand and finer material.

These abundant sediments may have their source in upstream mass-wasting deposits. Hillshade imagery derived from LiDAR (USGS and Quantum Spatial 2018) show large arcuate head scarps at the top of the hillslopes on either side of the channel (Figure 6), approximately 1,500 feet upstream of the crossing. These scarps indicate the approximate initiation point of the mass-wasting event. The released material is deposited in the channel and valley and is periodically transported downstream. Without a field reconnaissance, the extent of the sediment source cannot be verified, but it is likely that the abundance of observed finer sediments are related to these deposits. However, the slope of the channel and active engagement with the floodplain allow for in-channel transport of sediments and floodplain deposition of overbank sediments. There is one passage barrier downstream (Figure 4) of the scarps shown on Figure 6; however, given the sands observed in the channel, this barrier does not appear to restrict the movement of sand-sized sediments. Larger sediments may be trapped behind the upstream barrier.

Estimates of the long-term aggradation of the channel are based upon qualitative assessment of the incoming sediment supply, relative to transport capacity of the channel. Incoming sediment load is suspected to be elevated due to the nearby (0.25-mile upstream) presence of mass-wasting features and landslide deposits observed in hillshade imagery and identified in geomorphic mapping (Haugerud 2009). Under existing conditions, excess aggradation was not observed in the channel, but deposition was observed on the adjacent floodplain. During high-flood events, incoming sediment supply may exceed the transport capacity of the channel and crossing, facilitating deposition. Deposited sediments may also be reworked during subsequent flood events and transported out of the reach. These infrequent events may, over time, contribute to long-term aggradation of up to 1 foot. These estimates require corroboration by field investigation of the level of activity of the mass-wasting source and the availability of deposits for transport.

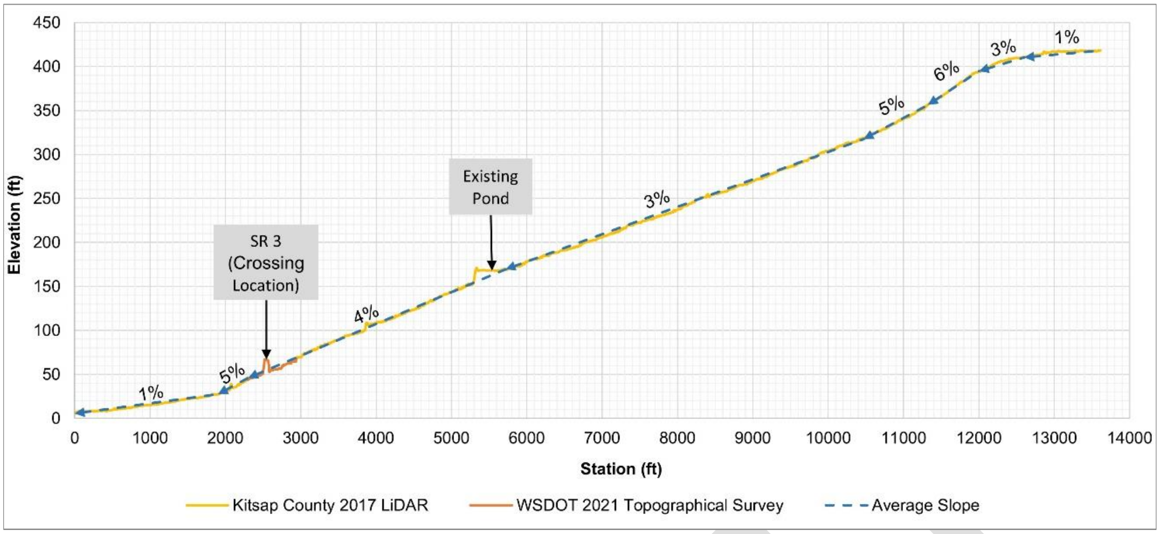


Figure 27: Watershed-scale longitudinal profile

2.7.5 Channel Migration

The potential for channel migration is a function of multiple factors, including historical migration, sediment supply, gradient, and bank stability. In the reach near the crossing, the UNT channel is a low risk for channel migration. The gradient through the reach is sufficient to transport the observed, incoming load of mostly sand-sized material. Limited flow paths through the floodplain were observed: discontinuous and resembling swales more than channels. The floodplain is also vegetated, limiting incision into the floodplain surface. Bank stability is high and engagement with a relatively wide and vegetated floodplain spreads overbank flows and reduces the available energy to create new channels.

3 Hydrology and Peak Flow Estimates

There is no historical flow data available for UNT to Kinman Creek. The nearest flow gage is the USGS Gage No. 12054000, located on the Duckabush River near Brinnon, nearly 16 miles west of the SR 3 culvert crossing. Peak flow estimates were developed using MGSFlood (MGS Software LLC. 2021) and validated using flow estimates from the USGS regression equations for Region 3 (Mastin et al. 2017). These are both hydrologic methods for ungaged locations described in WSDOT's *Hydraulics Manual* (2022a).

Both methods use the contributing area of the UNT to Kinman Creek watershed. The creek watershed boundaries were delineated using 3-foot resolution gridded LiDAR (USGS and Quantum Spatial 2018) and ArcHydro (ESRI 2021) terrain-processing routines within ArcGIS software as seen on Figure 2. Channel burning routines were not used because available depictions of hydrography, such as the National Hydrography Dataset and Ecology's stream dataset, are too coarse in resolution to adequately define the UNT to Kinman Creek channel. In addition to LiDAR terrain, culvert locations from the WDFW culvert database (WDFW n.d.-a) and utilities from the Kitsap County stormwater dataset (Kitsap County 2017) were used to guide watershed boundary delineation. The resulting watershed is 567 acres (0.9 square mile) in size.

MGSFlood was selected as the primary flow development method because it incorporates more refined hydrology methods based on land cover and soils. Calculations for MGSFlood, using a 15-minute time step and the USGS regression equations, are provided in Appendix N.

MGSFlood inputs are watershed areas associated with a combination of land cover and soil type. Land cover was estimated based on National Land Cover Database (MRLC 2019a; Section 2.2), and soil type was estimated based on a combination of subsurface geology (NRCS USDA 2021; Section 2.3) and Soil Survey Geographic Database (SSURGO) soils (NRCS USDA 2021; Section 2.3). Consistent with MGSFlood guidance (MGS Software LLC 2021), soils identified by SSURGO as hydrologic soil Group B used underlying geology to assign outwash and till soil designations. The USGS regression equation inputs include watershed area and mean annual precipitation. A mean annual precipitation of 38.1 inches was determined based on the 30-year climate normal (PRISM Climate Group, Oregon State University 2021). The USGS regression equations also provides lower and upper prediction intervals (PI_l and PI_u respectively), acknowledging the uncertainty associated with this method.

A sensitivity analysis was performed to determine critical hydrologic parameters within the MGSFlood model. The model was simulated in a 3-subbasin condition and a 1-basin condition to determine the sensitivity of time of concentration and routing. Channel cross sections needed for hydraulic routing in the 3-subbasin condition were derived from LiDAR and are provided in Appendix N. No as-built plans or aerial imagery of surface water storage or other hydrologic facilities were identified within the UNT to Kinman watershed. There is a small pond/detention (approximate area of 0.5 acre; 19,637 square feet) in subwatershed 991242B. The hydrology and mapping (USGS 2019) does not currently show this detention. Compared to the size of the pond with watershed, our approach is to calculate watershed outflow from the subbasin without considering detention.

Peak flow estimate results are provided in Table 6. MGSFlood results are similar (within -20 percent to +6 percent) to the USGS regression equation central estimates. Low summer flow conditions are not known and were not evaluated.

No field indicators were used to calibrate flows. However, the 2-year flow estimate was used to perform a simulation in the existing condition model in SRH-2D. The resulting top width of the model results were compared to field-measured BFWs within the reference reach. These comparisons showed top widths that were slightly larger than measured widths, with some overbank flow. This comparison indicates that the estimated flows are generally similar to those expected based on these field indicators.

WSDOT recognizes climate resilience as a component of the integrity of its structures and approaches the design of bridges and buried structures through a risk-based assessment beyond the design criteria. The largest risk to bridges and buried structures will come from increases in flow and/or sea level rise. The goal of fish passage projects is to maintain natural channel processes through the life of the structure and to maintain passability for all expected life stages and species in a system.

WSDOT evaluates crossings using the mean percent change in 100-year flood flows from the WDFW Future Projections for Climate-Adapted Culvert Design program. All sites consider the projected 2080 percent increase throughout the design of the structure. Appendix G contains the projected increase information for the project site. The design flow for the crossing is 54 cubic feet per second (cfs) at the 100-year storm event. The projected increase for the 2080, 100-year flow is 56 percent, yielding a projected 2080, 100-year flow of 84 cfs.

Table 6: Peak flows for Unnamed Tributary to Kinman Creek at SR 3

Mean Recurrence Interval	Selected Method - MGSFlood (cfs)	Check Method - USGS Regression Equation (Region 3) ([PI_l], Q_u, [PI_u] in cfs)
2	12	[8] 15 [31]
10	30	[15] 31 [65]
25	37	[18] 40 [86]
50	49	[20] 46 [103]
100	54	[23] 53 [120]
500	57	[28] 69 [172]
Projected 2080, **100**	**(84**; **+56%)**	**([43] 108 [268]**; **+56%)**

4 Water Crossing Design

This section describes the water crossing design developed for SR 3 MP 57.23 UNT to Kinman Creek, including channel design, minimum hydraulic opening, and streambed design.

4.1 Channel Design

This section describes the channel design developed for UNT to Kinman Creek at SR 3 MP 57.23. The proposed design utilizes two typical cross sections, one for the pool sections and one for the glide sections, that are implemented over the 219 feet of channel grading and described in further detail in Section 4.1.1. Additional information on the proposed alignment and gradient is provided in Sections 4.1.2 and 4.1.3, respectively.

4.1.1 Channel Planform and Shape

As mentioned in Section 2.7.1, the reference reach identified and considered in developing the preliminary design is located approximately 150 feet upstream of the culvert and extends for another 100 feet upstream in a forested area with well-vegetated and cohesive banks. Per the WCDG (Barnard et al. 2013) the planform and shape of each subreach within the proposed design were designed to mimic the reference reach with adjustments based on engineering and geomorphic judgements. The proposed glide geometry includes a 6-foot BFW, an 0.8-foot bankfull depth, and floodplain benches on both sides to mimic the upstream reference reach (Figure 28 and Figure 30). The bottom of the channel is flat, the banks are sloped at 1.5:1, and the floodplain is sloped at approximately 10:1. The spacing of the glides is within the range of spacing observed in the reference reach (25 to 50 feet). The steep bank slopes mimic what was seen in the reference reach; however, this can be difficult to construct and maintain. As such, fabric-encapsulated soil lifts should be considered during the final hydraulic design (FHD). The slope of the floodplain was selected to mimic the existing floodplain slopes in the reference reach. A transition to supply-limited conditions triggered the incision of the UNT to Kinman Creek into its Pleistocene alluvial fan. This has resulted in a confined stream valley with steeper floodplain slopes in this portion of the watershed.

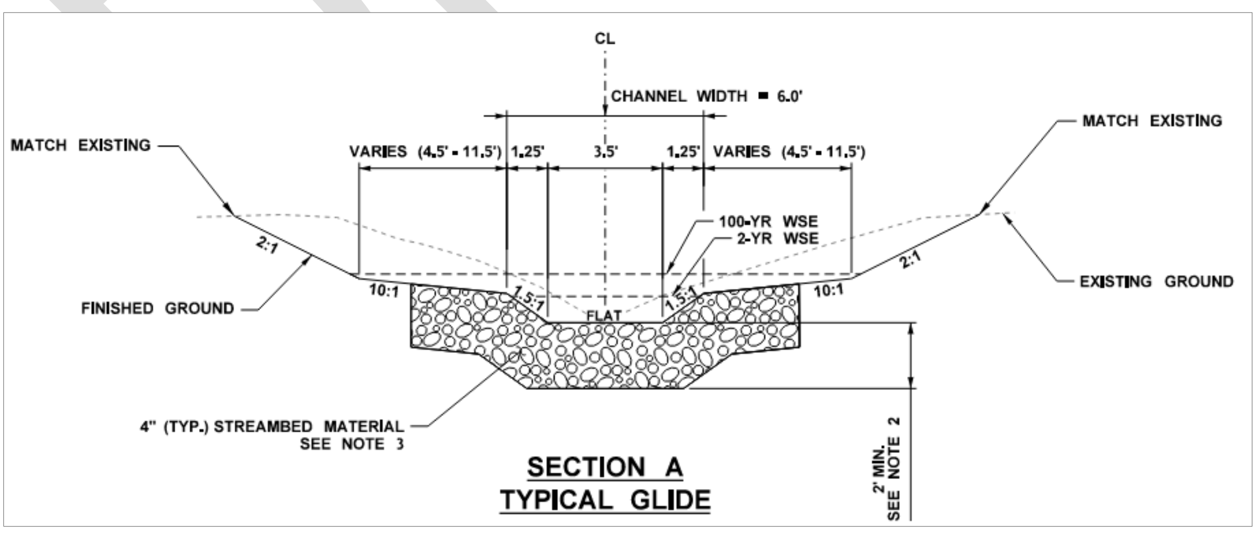


Figure 28: Proposed glide cross section

The proposed pool geometry includes an 8.5-foot BFW, a 1.8-foot bankfull depth, and floodplain benches on both sides that align with the proposed glide geometry. The bottom of the pool is flat, the banks are sloped at 1.5:1, and the floodplain slopes at approximately 10:1 (Figure 29).

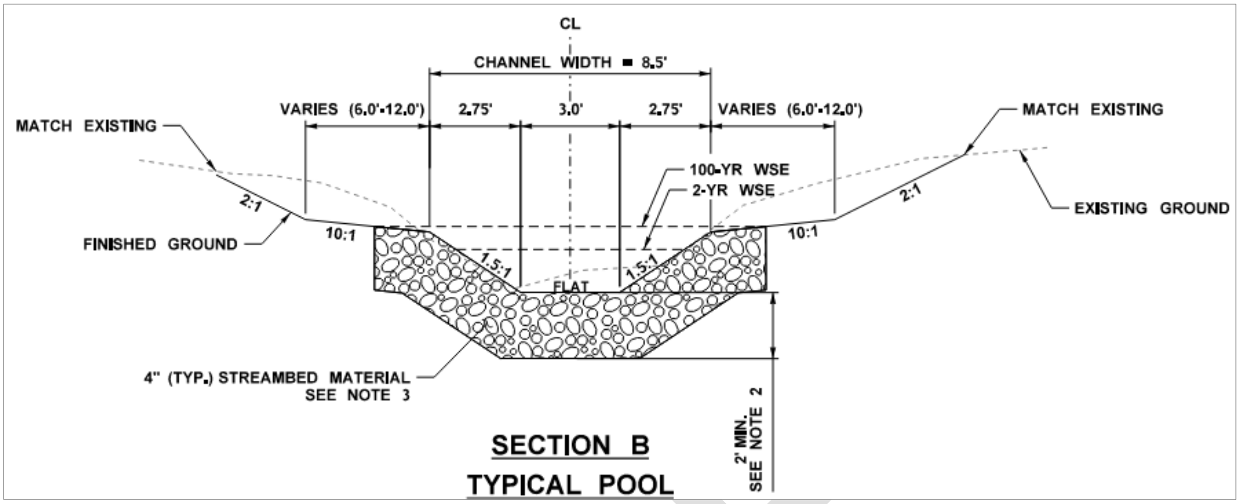


Figure 29: Proposed pool cross section

Forcing elements and half-channel coarse bands are periodically placed along both banks to reduce the risk of entrainment against the structure, (discussed further in Section 4.3.1). Outside of the 84-foot-long crossing, the graded surface slopes at 2:1 from the edge of the hydraulic opening to tie into the existing ground. Outside of the structure, the floodplain width is approximately 10 feet on the left bank and 7 feet on the right bank (Figure 30). See Appendix D for existing and proposed channel cross sections and planforms. The proposed channel will provide hydraulic characteristics similar to the reference reach. Model results show that 2-year event flows begin to expand beyond the BFW and engage the floodplain benches, as is the intent of this design. Furthermore, the 100-year velocity through the crossing is comparable to the velocity in the reference reach.

A low-flow channel will be added in later project stages to connect habitat features together so that the project is not a low-flow barrier. The low-flow channel, which will be triangular, will be constructed as directed by the engineer in the field. Information on the size of streambed material, forcing elements, and half-channel coarse bands is in Section 4.3.1.

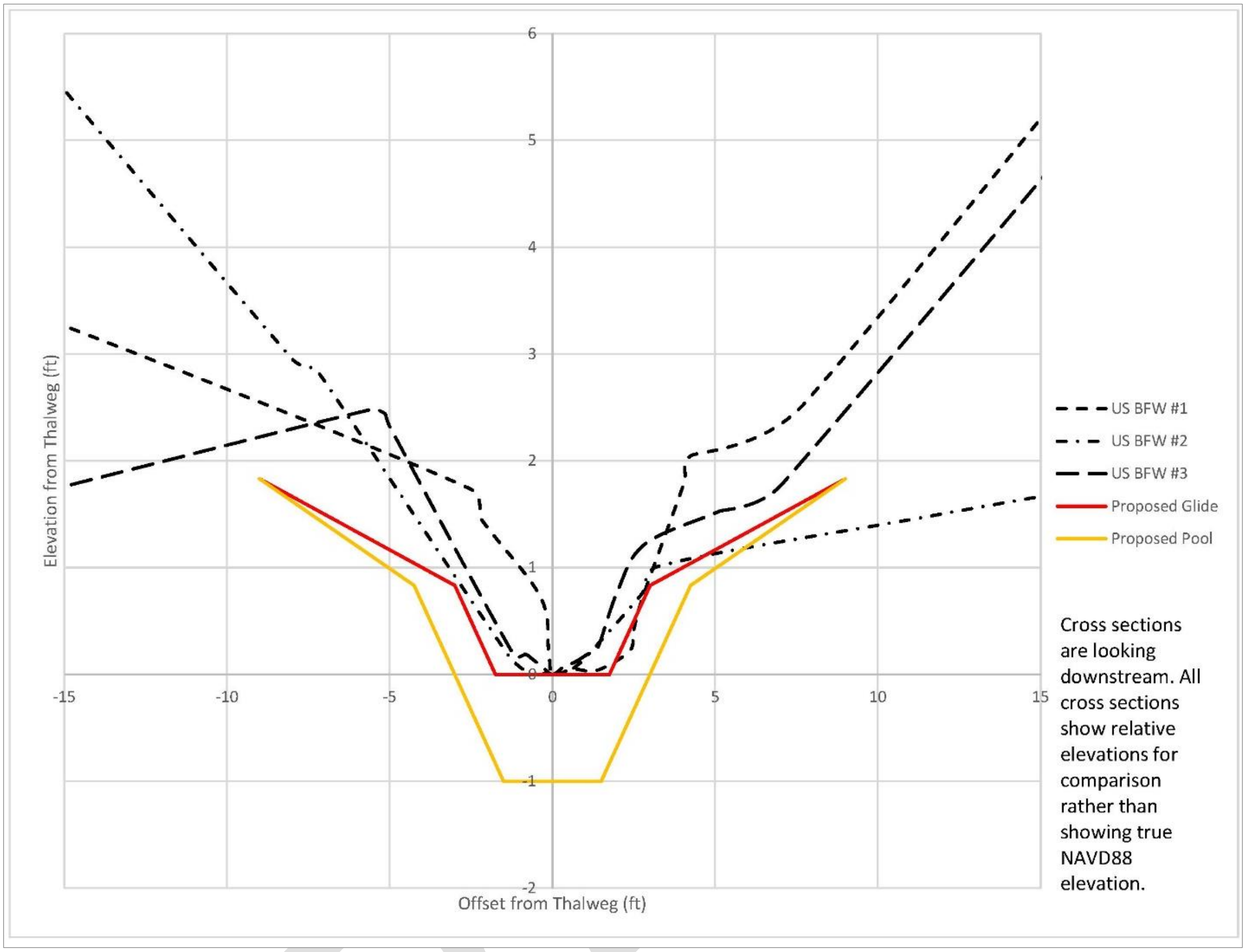


Figure 30: Proposed cross section superimposed with existing survey cross sections

4.1.2 Channel Alignment

A total of 219 feet of channel grading are proposed for the crossing. Ninety feet of regrading are inside the crossing and the remaining 129 feet are outside of the crossing. In existing conditions, roughly 50 feet of upstream channel is aligned immediately adjacent and parallel to the road. Upstream channel grading realigns the channel away from the road and creates floodplain on both sides of the channel for roughly 62 feet. Downstream of the crossing, the existing channel is confined in a steep, narrow ravine and is adjacent to one side of the ravine. Downstream channel grading realigns the channel to the center of the ravine and creates floodplain on either side of the channel for roughly 67 feet.

The proposed 219 linear foot stream realignment is at a slight skew to the roadway to limit disturbance of the upstream riparian corridor and limit downstream impacts of grading on adjacent property owners.

The new channel begins approximately 60 feet upstream of the proposed crossing to tie in-line to the existing thalweg. Approximately 5 feet is provided to transition between existing grade and the farthest proposed upstream and downstream pools. The proposed channel is relatively straight (sinuosity <1.1), with the exception of a single meander bend at the downstream end of the regrading. The sinuosity of the existing channel is 1.05 to 1.10, as noted in Section 2.7.2.

The downstream meander bend has a radius of curvature (Rc) of roughly 30 feet, compared to the Rc of existing meander bends (20 to 50 feet). For a BFW of 6 feet, the Rc to width ratio is at least 5. This ratio reduces the potential for erosion, particularly in a newly constructed channel (Cramer 2012). The proposed plan and profile sheets are in Appendix D, and vertical variability is discussed further in Section 4.1.3.

4.1.3 Channel Gradient

The stream immediately upstream of the existing culvert has a slope of 1.6 percent. The WCDG (Barnard et al. 2013) recommends that the proposed crossing bed gradient be within 25 percent of the existing stream gradient upstream of the crossing. Within the proposed pool and glide transitions, the channel glides have a 1.8 percent gradient, giving a slope ratio of 1.13. These transitions create undulations in the profile that provide vertical variability.

Long-term aggradation is expected due to the extensive, upstream mass-wasting. Fortunately, the channel has an active floodplain, where incoming excess sediment can be deposited. This “relief valve” may limit in-channel deposition to roughly 1 foot. Long-term degradation is not anticipated. Additional information on long-term aggradation and degradation is in Section 2.7.4 and Section 7.2, respectively.

4.2 Minimum Hydraulic Opening

The minimum hydraulic opening is defined horizontally by the hydraulic width, and the total height is determined by vertical clearance and scour elevation. This section describes the minimum hydraulic width and vertical clearance; for discussion on the scour elevation, see Section 7. Figure 31 shows the minimum hydraulic opening, hydraulic width, freeboard, and maintenance clearance terminology.

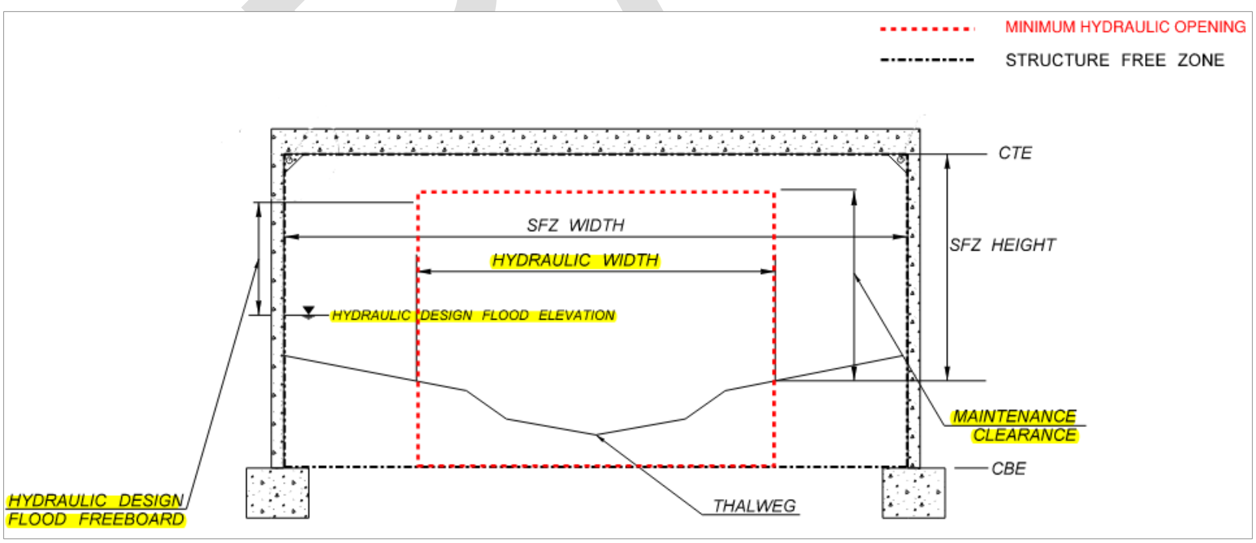


Figure 31: Minimum hydraulic opening illustration

4.2.1 Design Methodology

The proposed fish passage design was developed using WDFW's WCDG (Barnard et al. 2013) and WSDOT's *Hydraulics Manual* (2022a). WDFW's WCDG contains methodology for five different types of crossings: No-Slope Culverts, Stream Simulation Culverts, Bridges, Temporary Culverts or Bridges, and Hydraulic Design Fishways. The permanent federal injunction allows for the use of the stream simulation method and the bridge design method unless unsurmountable circumstances exist onsite (constraints of landownerships or infrastructure for example). According to the WCDG, a bridge should be considered for a site if any of the following should be met: the FUR is greater than 3.0, the BFW is greater than 15 feet, the channel appears unstable, the slope ratio exceeds 25 percent between the existing channel and the new channel, the channel is debris prone, or the culvert is very long (beyond 10:1 length-to-width ratio).

Using the guidance in the WCDG (Barnard et al. 2013) and the *Hydraulics Manual* (WSDOT 2022a), the unconfined bridge method through the crossing was determined to be the most appropriate. As noted in Section 2.7.2, the typical BFW is not greater than 15 feet. Sections 2.7.4 and 2.7.5 note that the existing channel appears to be stable laterally and vertically. Additionally, the FUR is greater than 3.0 (Section 2.7.2.1), the proposed crossing is not beyond the 10:1 length-to-width ratio (Section 4.2.4), and the slope ratio does not exceed 25 percent between the existing channel and the new channel (Section 4.1.3). Section 4.1.3 notes that the channel has low channel migration potential vertically and horizontally. Finally, Section 4.2.3 shows that the minimum hydraulic opening, with a wider floodplain, is sufficient enough to allow for BFW increase over time due to climate resilience.

4.2.2 Hydraulic Width

The starting point for the minimum hydraulic width determination of all WSDOT crossings is Equation 3.2 of the WCDG, rounded up to the nearest whole foot. For this crossing, with a 6-foot BFW, a minimum hydraulic width of 10 feet was determined to be the minimum starting point. To accommodate future channel sinuosity through the crossing and allow for natural processes to occur under current flow conditions, an 18-foot minimum hydraulic opening is proposed. This hydraulic opening is driven by the geomorphic processes outlined in Section 4.1; it mimics the reference reach in the typical glide and pool cross sections and the 100-year span. The 18 feet allow for a minimum of 4 feet between the proposed crossing wall and the top of the proposed banks; if a narrower minimum hydraulic opening was chosen, the channel could begin to entrain against the walls. Additionally, the 18-foot minimum hydraulic opening will accommodate peak flows and maintain an appropriate velocity ratio with adjacent reaches.

Table 7 shows the minimum hydraulic opening required for each metric compared to the chosen minimum hydraulic opening. Associated vertical clearance requirements are in Section 4.2.3 and hydraulic length is in Section 4.2.4.

Table 7: Minimum hydraulic opening summary

Metric	Minimum Hydraulic Opening (ft)
Equation 3.2 of the WCDG	10
Q100 Span	20
Meander Width	18
Chosen	**18**

Based on the factors described above, a minimum hydraulic width of 18 feet was determined necessary for allowing natural processes to occur under current flow conditions. The design team evaluated the projected 2080, 100-year flow event. Table 8 compares the main channel average velocities of the 100-year and projected 2080, 100-year events.

Table 8: Main channel average velocity comparison for 18-foot structure

Location	100-year velocity (fps)	Projected 2080, 100-year velocity (fps)	Velocity Ratio
Reference reach (STA P14+55) - Riffle	5.0	4.7	0.9
Reference reach (STA P14+50) - Step	6.6	7.2	1.1
Upstream of structure (STA P13+15)	4.7	5.3	1.1
Through structure (STA P12+55) - Riffle	5.2	5.9	1.1
Through structure (STA P12+50) - Step	6.6	7.2	1.1
Downstream of structure (STA P11+75)	4.3	4.6	1.1

In addition to the main channel average velocities, velocities on the floodplain average less than 3.5 feet per second (fps) at the 100-year flow event and average less than 4.7 fps at the Projected 2080, 100-year flow event. These lower velocities allow for refuge outside of the main channel during high flow events.

The velocity ratio at the outlet of the culvert is slightly above the WDFW WCDG (Barnard et al. 2013) however, this exceedance occurs at the edge of a step where velocities are expected to be higher. Table 9 indicates, that aside from this outlier, there is no appreciable difference in velocity between the proposed- and natural-conditions models.

Table 9: Main channel average velocity ratio comparison between proposed and natural conditions

Location	Proposed Condition 100-year velocity (fps)	Natural Condition 100-year velocity (fps)	Velocity Ratio
Structure Inlet (STA P12+90)	5.2	5.7	0.9
Through Structure Riffle (STA P12+55)	5.2	5.7	0.9
Through Structure Step (STA P12+50)	6.6	5.7	1.2
Through Structure Pool (STA P12+48)	5.6	5.7	1.0
Structure Outlet (STA P12+00)	5.2	5.3	1.0

No size increase was determined to be necessary to accommodate climate change. For detailed hydraulic results see Section 5.4.

4.2.3 Vertical Clearance

The vertical clearance under a structure is made up of two considerations: freeboard and maintenance clearance. Both are discussed below, and results are summarized in Table 10.

The minimum required freeboard at the project location, based on BFW, is 1.0 foot above the 100-year water surface elevation (WSE) (Barnard et al. 2013; WSDOT 2022a). Long-term aggradation and debris risk were also evaluated at this location. One foot of freeboard was added to account for the risk of aggradation/debris risk, resulting in a minimum required freeboard of 2 feet. More information on the risk for long-term aggradation is in Section 2.7.4.

WSDOT is incorporating climate resilience in freeboard, where practicable, and has evaluated freeboard at both the 100-year WSE and the projected 2080, 100-year WSE. The WSE is projected to increase by 0.3 foot for the projected 2080, 100-year flow rate. The minimum required freeboard at this site will be applied above the projected 2080, 100-year WSE to accommodate climate resilience.

The second vertical clearance consideration is maintenance clearance. WSDOT HQ Hydraulics determines a required maintenance clearance if a height is required to maintain habitat elements, such as boulders or LWM. If there are no habitat elements requiring maintenance clearance to maintain, the maintenance clearance is only a recommendation by WSDOT HQ Hydraulics, and the region determines the maintenance clearance required.

The channel complexity features in Section 4.3.2 do not include elements of significant size and will not need to be maintained with machinery. If it is practicable to do so, a minimum maintenance clearance of 6.0 feet from the highest point in the cross section is recommended for maintenance and monitoring purposes but is not a hydraulic requirement. Maintenance clearance is measured from the highest streambed ground elevation within the horizontal limits of the minimum hydraulic width.

Table 10: Vertical clearance summary

Parameter	Downstream face of structure	Upstream face of structure
Station	STA P12+00	STA P12+90
Thalweg elevation (ft)	50.5	53.3
Highest streambed ground elevation within hydraulic width (ft)	53.0	55.8
100-year WSE (ft)	52.0	54.8
2080, 100-year WSE (ft)	52.3	55.1
Required freeboard (ft)	2.0	2.0
Recommended maintenance clearance (ft)	6.0	6.0
Required minimum low chord, 100-year WSE + freeboard (ft)	54.0	56.8
Required minimum low chord, 2080, 100-year WSE + freeboard (ft)	54.3	57.1
Recommended minimum low chord, highest streambed ground elevation within hydraulic width + maintenance clearance (ft)	59.0	61.8
Required minimum low chord (ft)	**54.3**	**57.1**
Recommended minimum low chord (ft)	**59.0**	**61.8**

4.2.3.1 Past Maintenance Records

As noted in Section 2.1, WSDOT Area 3 Maintenance was contacted to determine whether there are ongoing maintenance problems at the existing structure because of LWM racking at the inlet or sedimentation. The maintenance representative indicated that there was no record of LWM blockage and/or removal or sediment removal at this crossing.

4.2.3.2 Wood and Sediment Supply

The watershed of the UNT to Kinman Creek is mostly evergreen forest, but wood and sediment supply could be interrupted by upstream road crossing. However, the project area has adjacent forest that facilitates recruitment of LWM, ensuring adequate wood supply.

There is likely abundant incoming sediment supply to the crossing from upstream mass-wasting deposits. Field observations indicate the incoming supply ranges from small gravel to sand. Aggradation at the crossing is not anticipated due to the increased transport capacity of the design channel. The placement of LWM could impact transport by creating small eddies around pieces that would facilitate local deposition, but higher flows periodically transport local deposits.

The observed riparian corridor is also an LWM source but transport may be limited due to the small size of the channel and the size of available LWM pieces. LWM generated by the riparian corridor is likely to form channel-spanning pieces or pieces too large for transport. The upstream watershed is relatively well forested, which should facilitate natural sourcing of sediment and wood.

4.2.4 Hydraulic Length

The structure length should be reduced from the existing 84-foot length to the extent practicable; however, an 18-foot-wide structure would allow a maximum 180-foot-long structure without requiring additional analysis and would allow for geomorphic processes, as discussed in Section 4.2.2.

4.2.5 Future Corridor Plans

Future corridor plans were requested from the WSDOT Project Engineer’s Office by the design team. At the time of preparing this preliminary hydraulic design (PHD), no corridor plans (if they exist) were provided.

4.2.6 Structure Type

No structure type has been recommended by WSDOT HQ Hydraulics. The layout and structure type will be determined at later project phases.

4.3 Streambed Design

This section describes the streambed design developed for SR 3 MP 57.23 UNT to Kinman Creek.

4.3.1 Bed Material

The bed stability approach was developed for the streambed aggregate material (SBM) design. This method uses empirical SBM stability equations to determine bed material incipient motion and selects the D_{50} or D_{84} (the particle size that is larger than 50 percent or 84 percent, respectively, of the nearby material) mobilized at a particular design storm event to achieve stability per the WCDG (Barnard et al. 2013). Final gradations of the bed stability approach are provided based on standard WSDOT streambed aggregate sizes and compared against empirically based streambed aggregate distributions.

The calculations present the final selected gradation, the natural gradation based on natural distribution ratios, the results of the Fuller Thompson analysis (Barnard et al. 2013), and the average pebble counts for the project location, if collected. After performing hydraulic and substrate mobility calculations using various methods, a single D_{84} is selected. The D_{84} is the basis for the gradation of the SBM in the chosen location. A specific WSDOT standard gradation (WSDOT 2022a) is then selected that most closely matches the final aggregate size. Results from the proposed 100-year and bankfull flood events were extracted from the proposed 2D hydraulic model. Maximum hydraulic values, such as flow area, critical depth, velocity, and hydraulic radius, were used as inputs to the incipient motion equations. The streambed aggregate mix calculations are in Appendix C.

As mentioned in Section 2.7.3, streambed material in the glide reaches is dominated by sand and silt (D_{50} <0.04 inch), and riffles are dominated by small gravel (D_{50} of 0.2 inch). Due to the small size of the existing material and using the approach above (specifically using the Modified Critical Shear Stress Design methodology), the suggested SBM is 50 percent WSDOT 4-inch streambed cobbles with 40 percent WSDOT standard streambed sediment and 10 percent streambed sand for the proposed main channel, as outlined in Table 11. Table 11 summarizes the observed grain size distribution versus the proposed grain size distribution. The proposed D_{50} is three times the observed riffle D_{50}. The observed riffle D_{50} is calculated from two pebble counts, each of which had a significant mode (10 to 12 percent) in sand-sized and finer sediments. This sand-sized and smaller fraction results in a lower D_{50} grain size, lower than if the sand-sized fraction had been excluded. These factors result in a larger than observed D_{50} grain size. However, the observed and calculated D_{16} and D_{100} grain sizes are approximately the same. The D_{84} of the proposed streambed material remains stable up to and through the 2-year event. At flow events higher than the 2-year event, it is anticipated that transported bed material will then be replaced from the stored sediment upstream of the crossing. The initial mobility of the streambed allows for the channel to naturally adjust over time. This means the channel widths will begin to increase while channel depths begin to decrease; these changes will result in a decrease in shear stresses and therefore less mobile streambed material.

Due to the sediment supply, this system is determined to be a low risk, according to the Streambed Material Decision Tree in WSDOT's *Hydraulics Manual* (2022a). Jacobs suggests that the material through and downstream of the crossing be placed in lifts and washed with fines to fill in void space; this will be considered further in the FHD. As mentioned in Sections 2.4 and 2.6.3, the stream width, depth, gradient, and substrate is suitable for rearing, migration, and spawning of resident and sea-run cutthroat trout and is modeled as suitable for migration and spawning of steelhead and coho.

The crossing will have several forcing elements and half-channel coarse bands along the crossing walls to avoid entrainment, maintain channel shape, and maintain the sinuous thalweg over time. Additional information on the purpose of these channel complexity features is provided in Section 4.3.2.

Current guidance on forcing element design (Heilman 2022) suggests that the head of the forcing element should be stable at the 100-year flow and the tail should be at least 50 percent or greater than the D_{84} grain size. The proposed material for the forcing elements (Table 11) meets these requirements. Initial calculations suggest the use of 10 percent WSDOT 12-inch streambed cobbles, 60 percent one-man boulders (12 to 18 inches in size), and 30 percent WSDOT standard streambed sediment for the heads of these larger features. Additionally, initial calculations suggest the use of 60 percent WSDOT 12-inch streambed cobbles, 10 percent one-man boulders (12 to 18 inches in size), and 30 percent WSDOT standard streambed sediment for the tails of these larger features. The design team predicts that this material is oversized due to the limitations of the calculations used at this PHD level of analysis. The proposed streambed mix for forcing elements and half-channel coarse bands should be evaluated during the scour analysis in the FHD. Additional pebble counts should also be performed at existing step-pools within the reference reach to help determine appropriate material sizing in these locations. Additionally, grab samples would help show what the stream base sediments are and are recommended for the FHD. The location of the forcing elements and boulders are shown on Figure 32.

Table 11: Comparison of observed and proposed streambed material

Sediment size	Observed diameter for glides (in)	Observed diameter for riffles (in)	Proposed diameter (in)	Forcing Element/ coarse band head diameter (in)	Forcing Element/ coarse band tail diameter (in)
$\mathbf{D_{16}}$	0.02	0.1	0.1	0.6	0.5
$\mathbf{D_{50}}$	0.04	0.4	1.2	13.0	3.0
$\mathbf{D_{84}}$	0.3	1.3	2.6	16.4	11.0
$\mathbf{D_{95}}$	1.0	2.1	3.5	17.5	15.0
$\mathbf{D_{100}}$	5.5	3.0	4.0	18.0	18.0

4.3.2 Channel Complexity

This section describes the channel complexity of the streambed design developed for SR 3 MP 57.23 UNT to Kinman Creek.

4.3.2.1 Design Concept

Complexity in the crossing and regraded reach will be provided by a slightly sinuous planform, LWM structures placed upstream and downstream of the crossing, and habitat and channel-forming features in the crossing. The LWM structures are placed to engage with the channel beginning at low flow. Forcing elements (above-grade structures designed to facilitate flow turning and meander bends developing) are placed on the inside of meander bends, inside the crossing. Half-channel coarse bands (below-grade structures designed to prevent channel incision and realignment against the structure wall) are placed on the left bank of the channel, inside the crossing. Crests within the profile are created by deformable steps. These steps mimic the observed steps, which commonly consist of tree roots and organic debris accumulations and enable flatter gradient glides to form, just as observed in the reference reach.

Half-channel coarse bands within the structure mimic the natural steps observed in the reference reach and will be used to prevent bed incision at pools and prevent realignment adjacent to the structure wall. The proposed forcing elements provide habitat value through localized scour pools and flow deflection, which creates variable flow patterns and encourages the development of meander bends. These forcing elements are located to ensure that the glides do not align themselves along the structure wall between the coarse bands. The forcing element elevations vary from the 10-year elevation at the structure wall to the 2-year elevation at the top of the channel bank. Additional information on sizing of forcing elements and half-channel coarse bands is in Section 4.3.1.

Deformable steps are crests in the profile that slow upstream flow and facilitate pre-formed pool maintenance immediately downstream. They are formed of coir fabric rolled around a core of coarse streambed material with adequate fines to prevent flows from going subsurface through the step. The deformable step is underlain by coarse band, which provides a stable foundation for the step. Over time, the step may accrete small woody material and organic debris, similar to steps observed in the reference reach. Step height is limited due to the maximum hydraulic drop being limited to 0.8 feet as specified in WDFW's WCDG (Barnard et al. 2013) to prevent fish stranding.

LWM is specified in regraded channel reaches upstream and downstream of the crossing. LWM is designed according to WSDOT (2022a) and Fox and Bolton (2007). The LWM should meet and exceed the sizing and characteristics of the reference reach by providing habitat, geomorphic function, sediment storage, bank stability, and hydraulic roughness. The existing LWM is limited both upstream and downstream of the existing culvert with no pieces providing the key piece function. Due to the location and small size of the tributary, the site is not likely used for recreation, swimming, or boating. Potential current and future use for fishing may occur, thus the LWM would be low impact to the recreational user.

The proposed design for the LWM (Figure 32) shows the proposed 30 pieces of wood to be placed within the 219-foot graded channel, with exception of a 90-foot segment for the roadway crossing. No LWM is recommended to be placed under SR 3 due to the size of the crossing. As of this time, the LWM design is conceptual and will need to be field verified in the FHD. The proposed design meets and exceeds the 75th percentile of the number of key pieces and total number of pieces as estimated by Fox and Bolton (2007). However, due to the small size of UNT to Kinman Creek, the proposed design does not meet the 75th percentile but does meet and exceed the 50th percentile of the total volume suggested by Fox and Bolton (2007). A comparison of the Fox and Bolton targets and the proposed design values of LWM is in Table 12. The LWM calculations are provided in Appendix F.

Table 12: Project reach LWM loading

LWM Loading Component	Design Criteria (75th percentile)[a]	Design Criteria (50th percentile)[a]	Proposed Design
Total pieces (quantity)	25	19	34
Total volume (cubic yards)	86.5	44.5	50.2
Key Pieces (quantity)	7	4	14

a. Calculated based on Fox and Bolton (2007) metrics using a project reach of 219 feet and a BFW of 6 feet.

The types of LWM structures are as follows:

Type 1: These surface-placed LWM structures consists of two wood pieces placed upstream and downstream of the structure in a "V" shape. The tree boles are crossed over each other with one bole protruding into the channel. The small piece protruding into the channel is ballasted by a medium piece. This structure provides local turbulence through local redirection of flow and provides complexity through local scour and deposition.

Type 2: These surface-placed LWM structures consist of one large piece, one medium piece, and one small wood piece. These structures are placed over the main channel, upstream and downstream of the proposed crossing, where the medium and small pieces interact with the low flow and the large piece provides self-ballasting while interacting with high flows. The tree boles are crossed over each other while the rootwad of the large piece is placed into the channel. This structure has a similar function to Type 1 structures by providing local turbulence through local redirection of flow and complexity through local scour and deposition, while also simulating an undercut bank.

Type 3: These surface-placed LWM structures consists of two layers; the top layer is a key piece and a large piece, both with rootwads, over a layer of a medium piece and a large piece. The base layer is placed, partially buried as needed, into the bank orthogonal to the flow direction, engaged at low flow and bankfull flow to provide hydraulic roughness and aquatic habitat. Both top layer pieces are surface placed at a skew to the flow direction with partial engagement at bankfull flow to promote redirection of the stream, roughness during high-flow events, and self-ballasting the lower layer. The key piece rootwad faces downstream; meanwhile, the top layer large piece rootwad is on the bank simulating a fallen tree. The large number of pieces in this structure is meant to provide regions of high-flow refugia, to offer a more complex habitat structure, and to develop controlled scour and potential dislodgement of small and very small pieces.

At the FHD, the orientation of structures will be refined for additional functions, such as creating undercut banks, and for additional means of anchoring, such as passive burial. All structures will be confirmed to remain stable up to and through the 100-year flow event by either anchoring or by virtue of the structures' weight, configuration, and orientation. All LWM stability calculations will be completed in the FHD to validate the stability of all LWM structures and help determine whether anchoring is needed.

No LWM structure type is designed to change channel planform, but facilitate in-channel change, such as local scour and deposition. Preformed pools are recommended around larger rootwads to anticipate future scour. All pools, preformed or not, would provide resting areas for the fish listed in Section 2.4. Additional habitat components of the proposed LWM design include providing structural habitat through pool and refugia formation as well as shade and food-sourcing promotion of aquatic organisms for fish. The proposed channel was designed to maintain a low-flow area; however, a seasonable hydrologic analysis was not performed as the channel complexity features will promote concentrated low-flow areas to reduce fish stranding.

The proposed design improves ecological integrity by providing LWM that interacts with the active channel and a less-straightened channel, which provides instream habitat for all aquatic organisms. Additionally, all of the proposed LWM is surface placed and self-ballasted rather than buried, which allows for a lesser grading and clearing impact. With a smaller footprint, more riparian vegetation can remain in place and continue to function properly, with a well-developed root mass to help stabilize banks, a well-developed canopy to provide shade and LWM recruitment, and a developed understory.

4.3.2.2 Stability Analysis

Large wood stability analysis will be completed at final design.

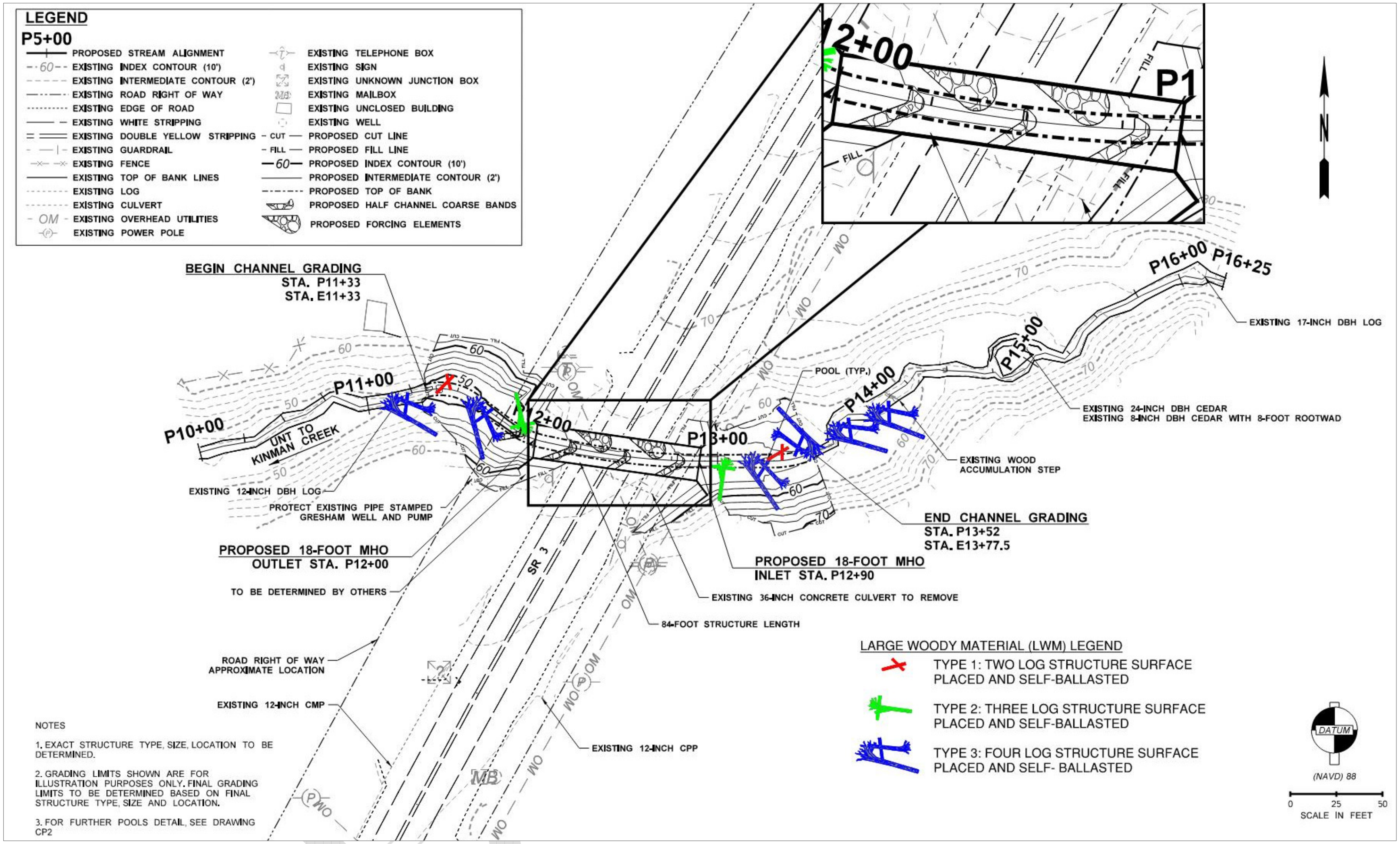


Figure 32: Conceptual layout of habitat complexity

5 Hydraulic Analysis

The hydraulic analysis of the existing and proposed SR 3 UNT to Kinman Creek crossing was performed using the United States Bureau of Reclamation's SRH-2D Version 3.3.1 computer program, a two-dimensional (2D) hydraulic and sediment transport numerical model (U.S. Bureau of Reclamation 2020). Pre- and post-processing for this model was completed using SMS Version 13.1.17 (Aquaveo 2020).

Three scenarios were analyzed for determining hydraulic characteristics for UNT to Kinman Creek with the SRH-2D models: (1) existing conditions with the existing 36-inch-diameter, 84-foot-long precast concrete culvert, (2) proposed conditions with the proposed 18-foot-wide structure beneath SR 3, and (3) natural conditions with removing the highway prism from the existing-conditions terrain and interpolating between the upstream and downstream cross sections. See Appendix H for a complete set of output figures.

5.1 Model Development

This section describes the development of the model used for the hydraulic analysis and design.

5.1.1 Topographic and Bathymetric Data

The channel geometry data in the model were obtained from the MicroStation and InRoads files supplied by the WSDOT Project Engineer's Office, which were developed from topographic surveys performed by WSDOT (2021a). Proposed channel geometry was developed from the proposed grading surface created by Jacobs. All survey information is referenced against the North American Vertical Datum of 1988 (NAVD88).

The only structural hydraulic control in the project area is the existing UNT to Kinman Creek crossing. Upstream controls on channel grade consist of periodic woody material and live tree roots.

The topographic survey provided adequate detail of step-pool features found within the channel for them to be incorporated into the existing-conditions model. The proposed grading surface that was created by Jacobs also included detailed step-pool features in the topography through the crossing. These features were incorporated into the model to inform design.

5.1.2 Model Extent and Computational Mesh

The existing condition model mesh includes approximately 24,000 elements across an area of approximately 1 acre. The mesh was constructed with quadrilaterals that are approximately 1- by 1.5-foot in the main channel, while the overbank mesh was constructed with triangles varying in size from 0.14 square feet near the main channel to 24 square feet at the exterior of the model domain. The main channel is comprised of 10 elements laterally spanning the BFW to sufficiently capture details of the channel within the mesh.

The proposed-condition model mesh is similar to the existing-conditions mesh except at the proposed SR 3 crossing. The proposed mesh includes quadrilateral mesh elements to represent the channel and overbank through the crossing, and the structure walls are represented as holes in the mesh. The number of elements and element size and spacing is consistent with the existing-conditions mesh. For both the existing and proposed meshes, the element length and width within the channel were selected to adequately represent the details provided in the topographic survey, LiDAR, and proposed grading elements. Additional detail on how topographic elements are included in the mesh is provided in Section 5.2 through Section 5.4.

Upstream of the SR 3 crossing, the model extends approximately 330 feet upstream. The downstream extent of the model is roughly 200 feet downstream of the outlet. Based on upstream and downstream floodplain widths (39 feet and 16 feet, respectively), the model has adequate length to ensure boundary conditions do not influence results. Furthermore, a sensitivity analysis was performed on the downstream boundary conditions. The constant WSE downstream boundary condition was increased by 1 foot and decreased by 1 foot. Model results showed that WSEs within the domain converged approximately 80 feet upstream from the downstream boundary condition.

Figure 33 and Figure 34 show the extent of the model mesh and generalized flow paths for the existing conditions, respectively. Figure 35 and Figure 36 show the extent of the model mesh and generalized flow paths for the proposed conditions, respectively. The lateral and longitudinal extent of the mesh captures the hydraulic processes present at the crossing. Information on the natural-conditions model extents and computational mesh are provided in Section 5.3.

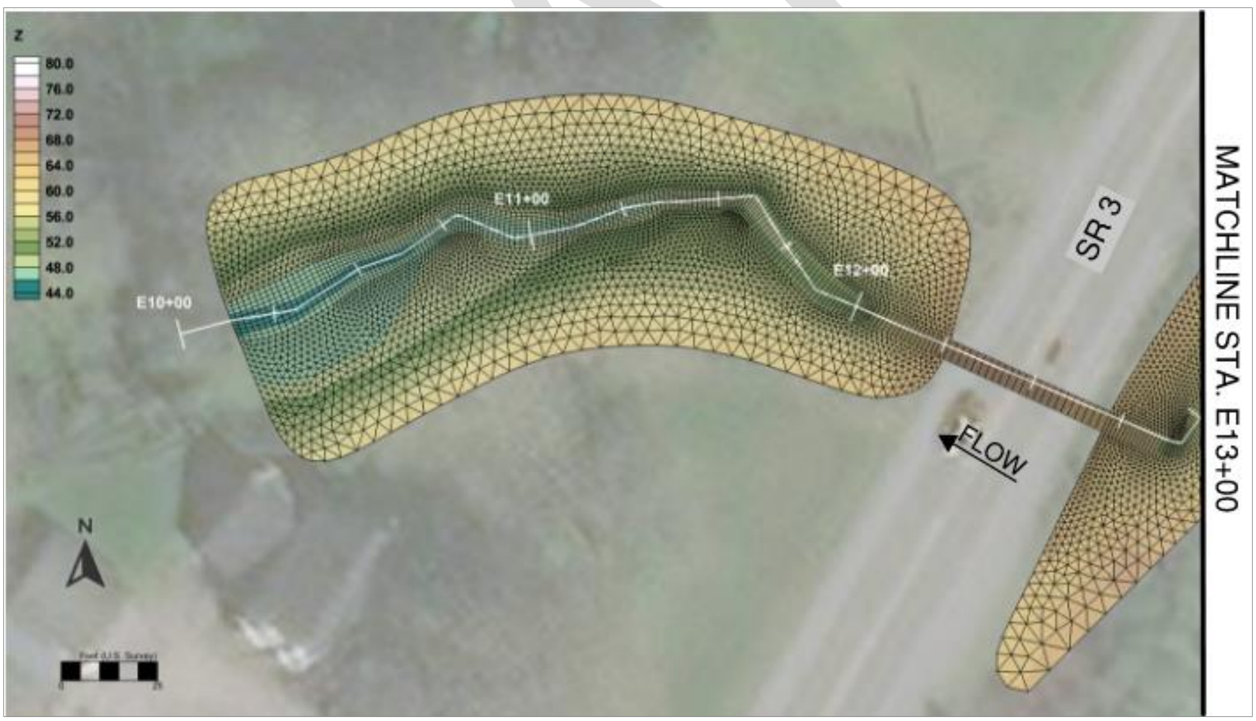


Figure 33: Western portion of existing-conditions computational mesh with underlying terrain.

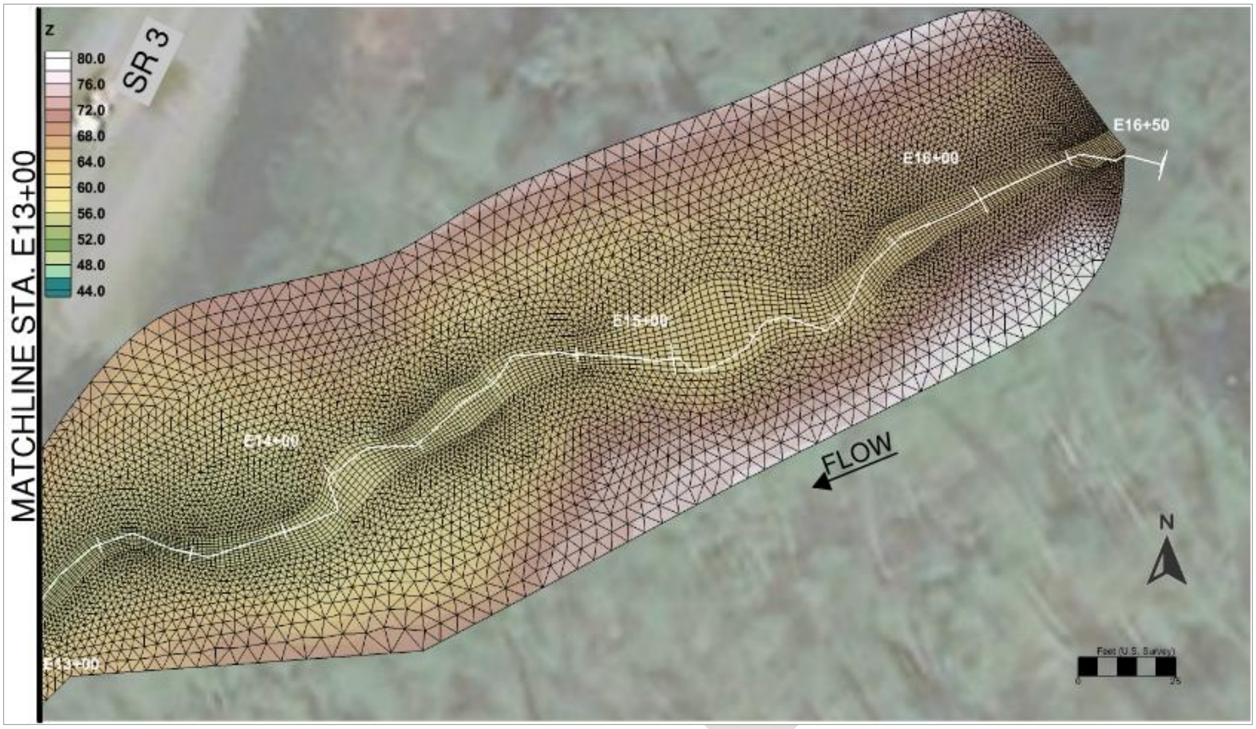


Figure 34: Eastern portion of existing-conditions computational mesh with underlying terrain.

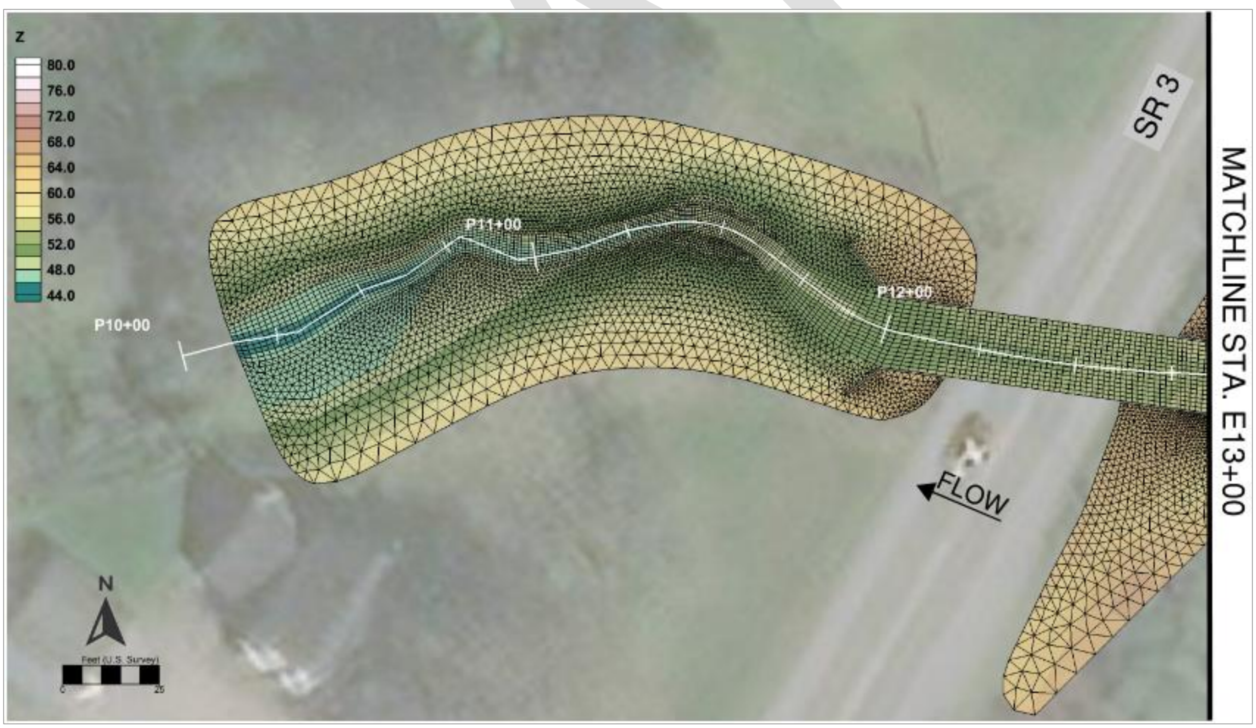


Figure 35: Western portion of proposed-conditions computational mesh with underlying terrain.

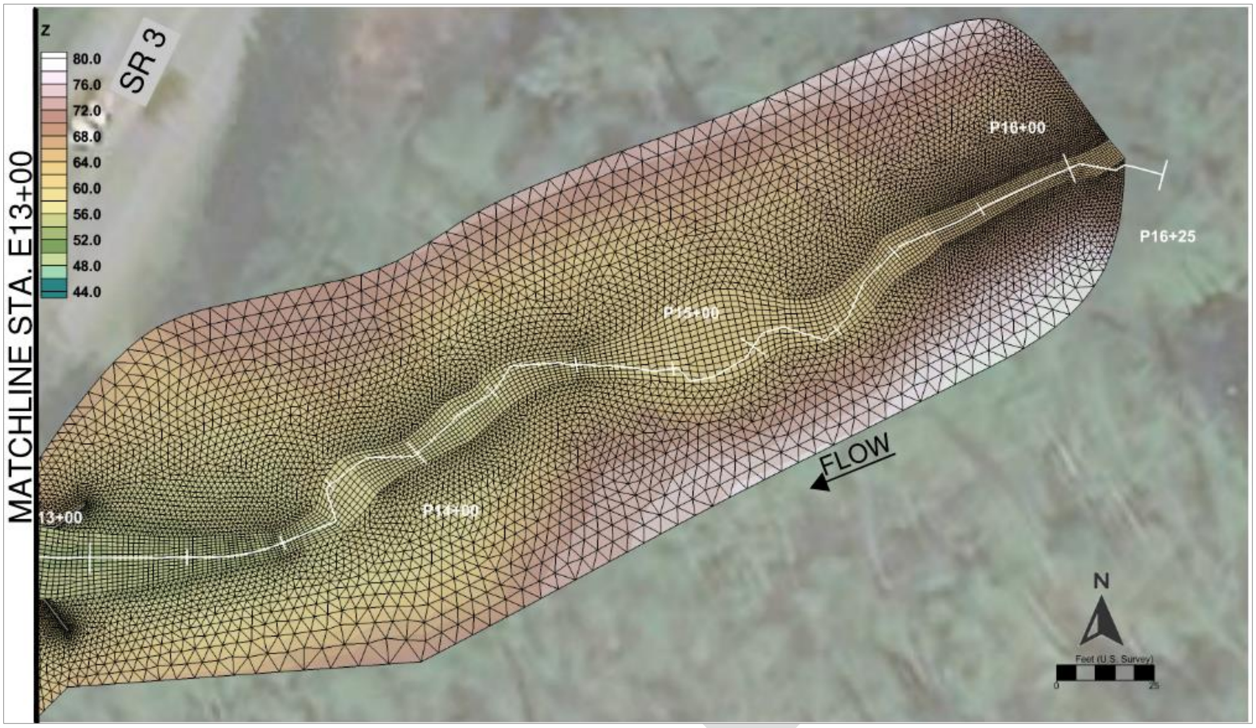


Figure 36: Eastern portion of proposed-conditions computational mesh with underlying terrain.

5.1.3 Materials/Roughness

The roughness coefficient is a composite value representing two forms of flow resistance: form drag and skin friction. Both affect hydraulic conditions (such as WSE, velocity, and shear stress) and the energy that is available to transport sediment. Form drag represents large-scale impediments to flow, including bends, point bars, LWM, or vegetation, and is highly dependent on flow depth and velocity. Skin (or grain) friction are the individual particle characteristics interacting with fluid at the fluid/soil boundary. Discrete roughness elements will be incorporated during the FHD.

Four pebble counts, two in riffles and two in glides, were performed upstream of the existing culvert (see Section 2.7.3). Channel and floodplain roughness were determined based on the prevalence and density of observable resistance elements, such as wood, vegetation, and channel and bank irregularity with guidance from the *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* (Arcement et al. 1989) and *Open Channel Hydraulics* (Chow 1959).

Results of the roughness parameterization for existing and proposed conditions are summarized in Table 13. The proposed channel and floodplain roughness are based on the streambed material size (see Section 4.3.1) and Limerinos' (1970) equation for roughness (*n)* for small gravel to medium-sized boulder streams, shown below, where *R* is the hydraulic radius and D_{84} is the grain size that 84 percent of the sampled bed material is smaller than.

$$\mathrm{n} = \frac{(0.0926 * R^{\frac{1}{6}})}{1.16 + 2.0 * log(\frac{R}{D_{84}})}$$

Spatial distributions of roughness values in the existing and proposed model are shown on Figure 37 and Figure 38, respectively. Information on the natural-conditions materials/roughness is provided in Section 5.3.

Table 13: Manning's *n* hydraulic roughness coefficient values used in the SRH-2D model

Material	Manning's *n*	
	Existing Conditions	Proposed Conditions
Existing Channel	0.046	0.046
Existing Overbank	0.06	0.06
Existing Floodplain	0.08	0.08
Proposed Streambed Mix (based on Limerinos, 1970)	—	0.04
Proposed Meander Bar (based on Limerinos, 1970)[a]	—	0.069
Large Woody Material	—	0.12

a. Features are not traditional meander bars but instead coarse bands and forcing elements as mentioned previously. The nomenclature "Proposed Meander Bar" is kept here for consistency with Figure 38.

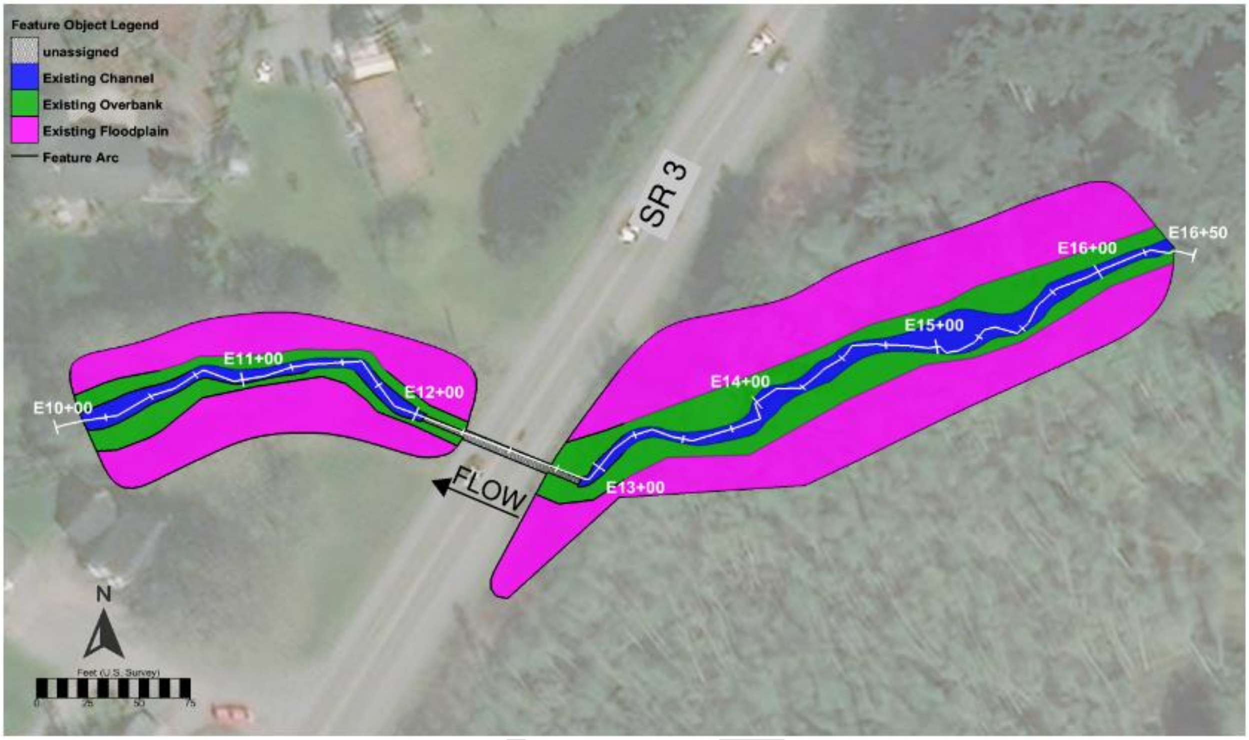


Figure 37: Spatial distribution of existing-conditions roughness values in SRH-2D model

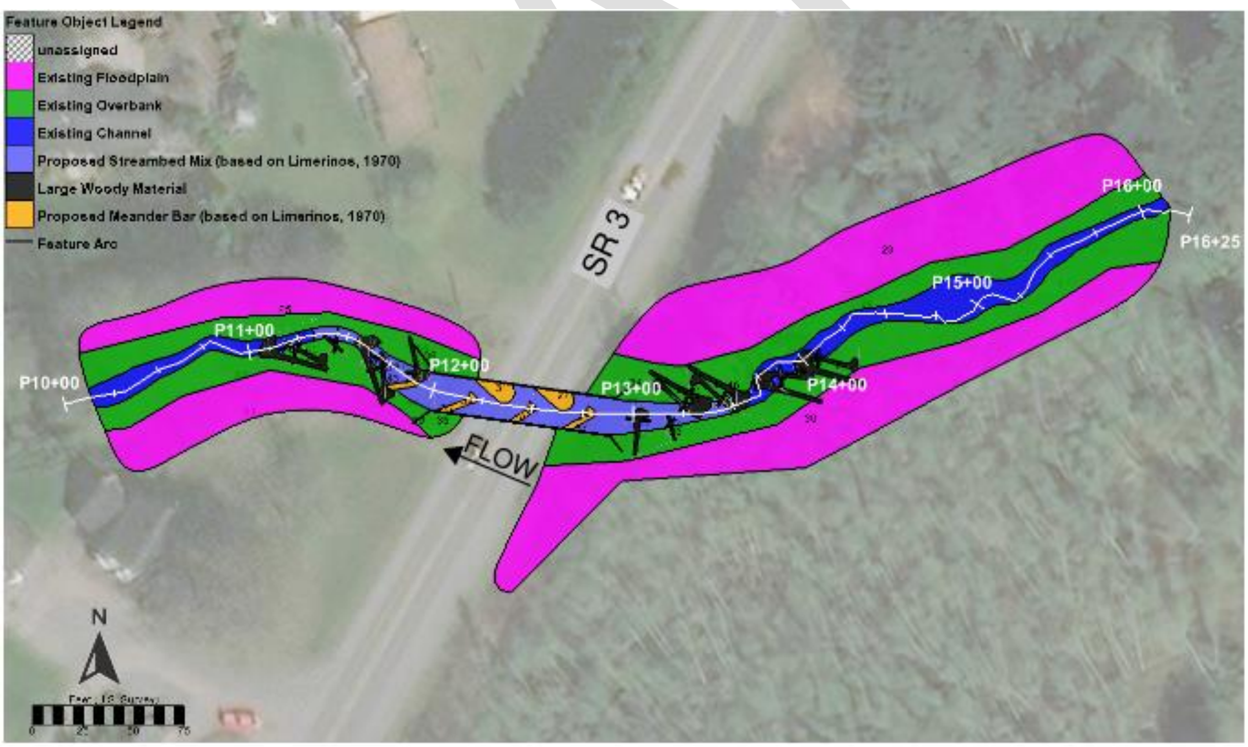


Figure 38: Spatial distribution of proposed-conditions roughness values in SRH-2D model

5.1.4 Boundary Conditions

The boundary conditions for the existing model includes a single inflow boundary and outflow boundary. The existing culvert was modeled using the integrated HY-8 routine to pass flow through SR 3, these boundary condition locations (labeled as HY-8 BC) are shown on Figure 39. The inflow (labeled as Inflow BC) and outflow (labeled as Outflow BC) locations for the existing and proposed conditions are shown on Figure 39 and Figure 40, respectively.

Inflow boundary conditions used in the model were subcritical Inlet-Q boundary conditions that introduced constant flow to the model at each mean recurrence interval (MRI). Flow values for each MRI are provided in Section 3 of this report. Outflow boundary conditions used in the model were subcritical Exit-H boundary conditions that solved for normal depth based on the underlying topography, a composite Manning's roughness, and flow.

The proposed crossing on Figure 40 was modeled as a hole in the mesh, which allows the crossing to be represented with vertical walls and the flows through the crossing to be evaluated. The HY-8 culvert hydraulic inputs for this crossing is shown on Figure 41. The outflow boundary condition rating curve is shown on Figure 42. Information on the natural-conditions boundary conditions is provided in Section 5.3.

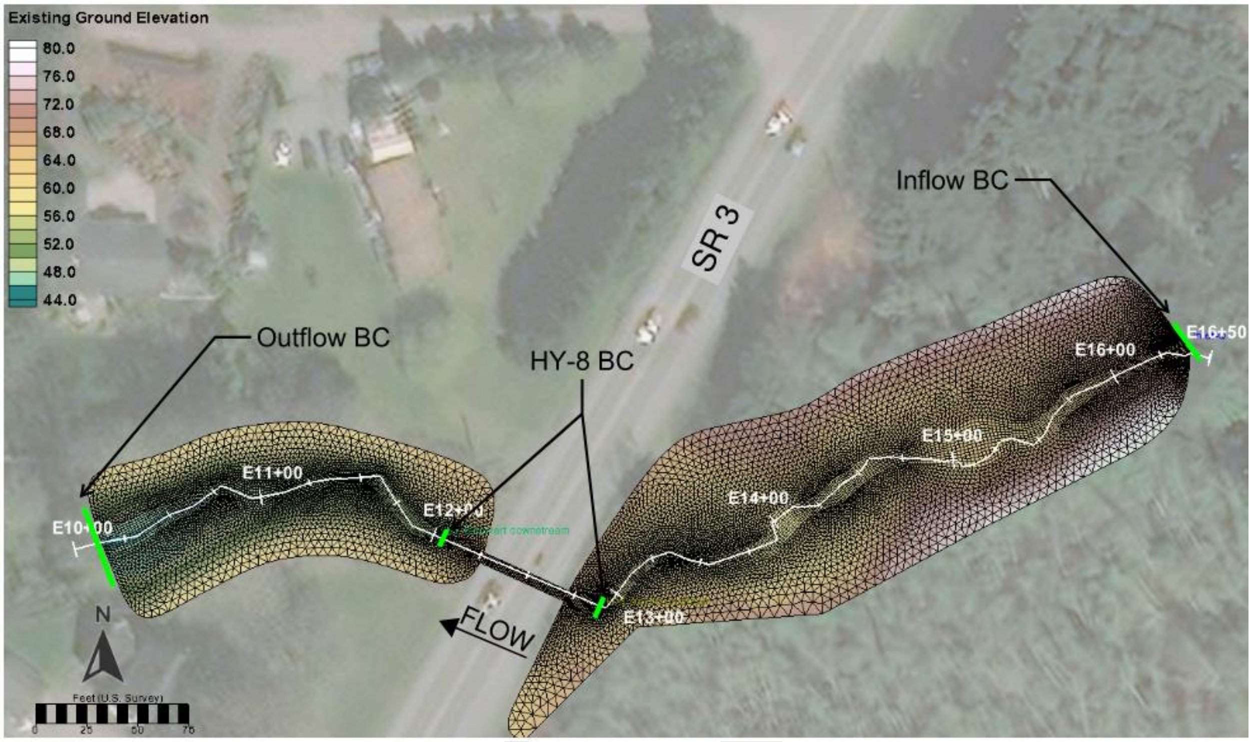


Figure 39: Existing-conditions boundary conditions

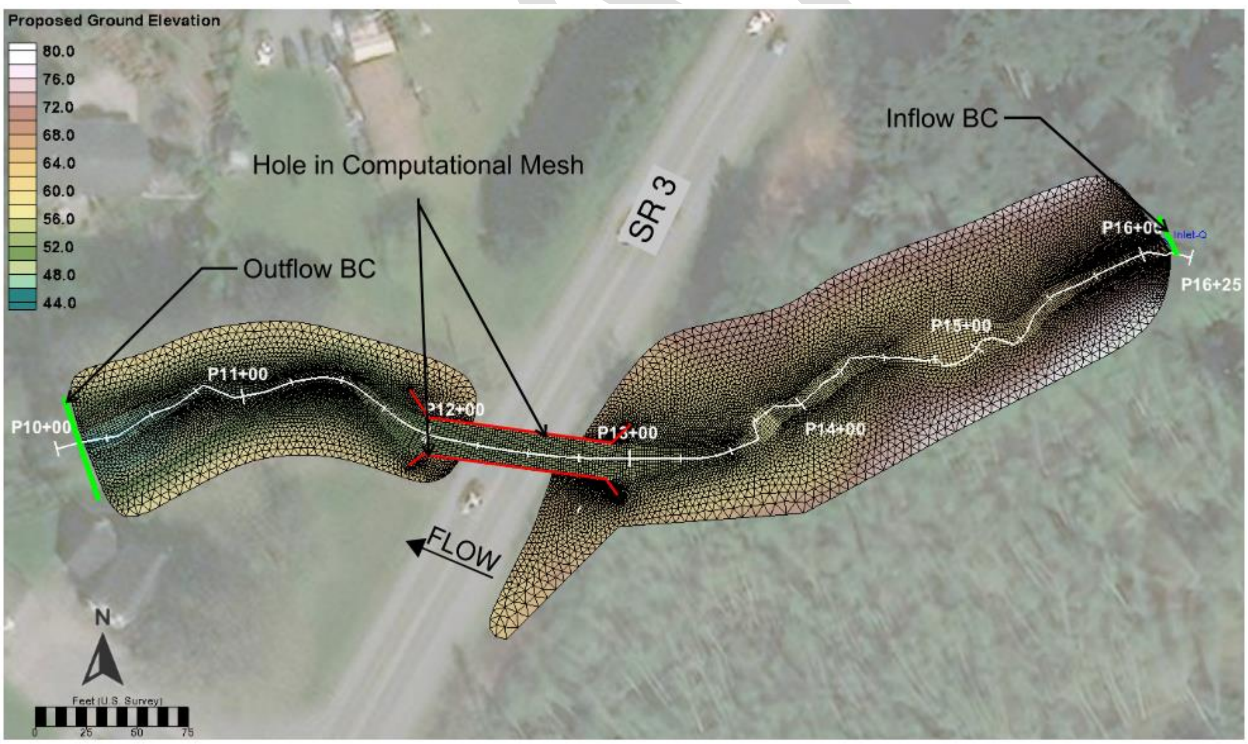


Figure 40: Proposed-conditions boundary conditions

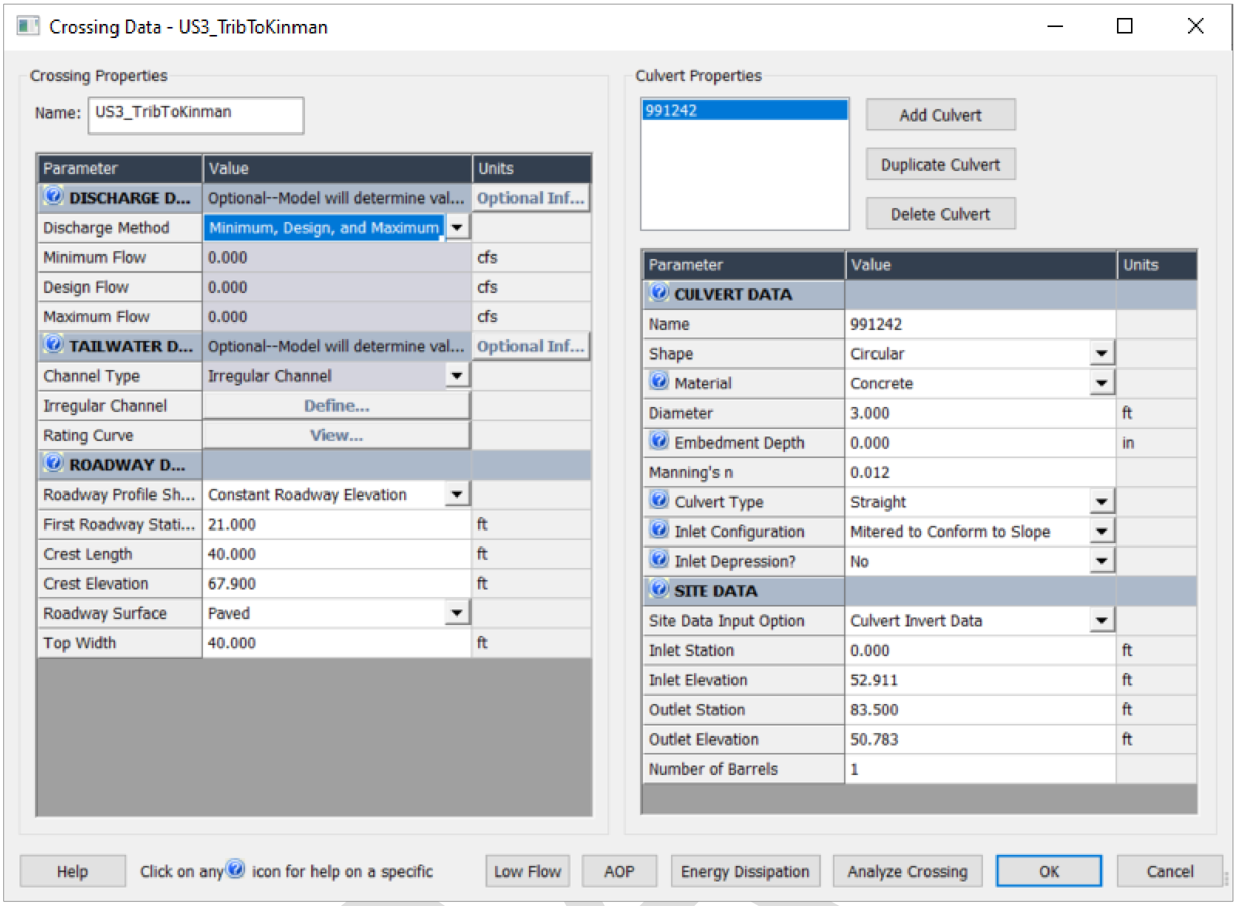


Figure 41: HY-8 culvert parameters

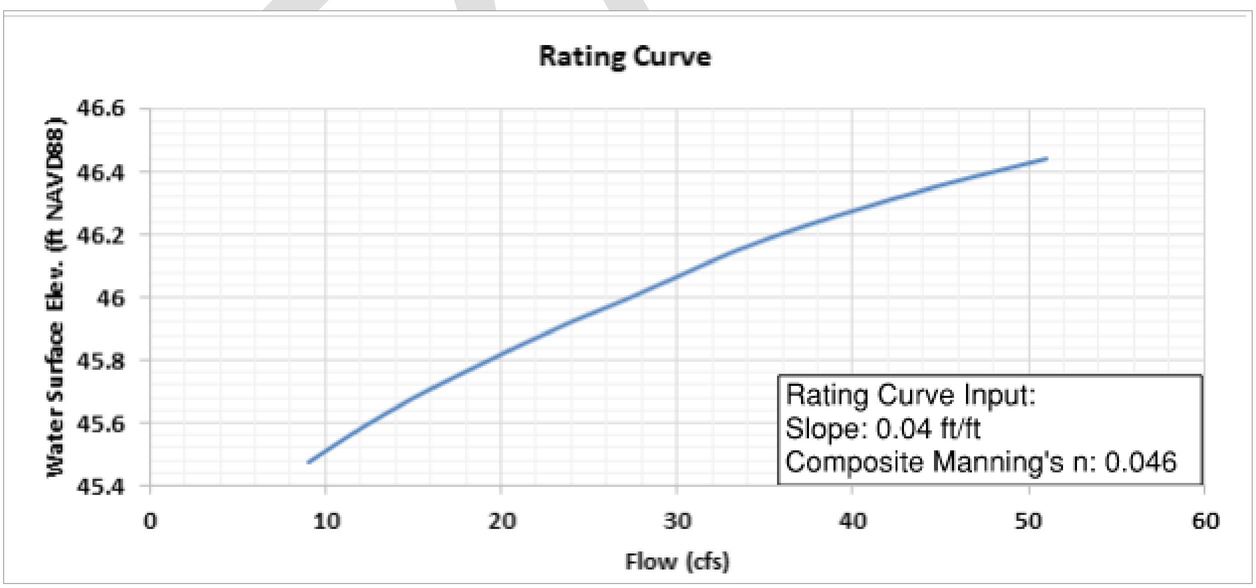


Figure 42: Downstream outflow boundary condition normal depth rating curve

5.1.5 Model Run Controls

Jacobs ran the existing- and proposed-conditions scenarios for 3 hours; the outlet of the model domain reached a stable steady-state condition after approximately 1 hour. Appendix I contains additional information regarding model stability. Other parameters were set as follows:

- Start time is default 0.0 hour
- Time step is default 0.25 seconds
- End time is 3.0 hours
- Initial conditions value is default dry
- Flow module was default parabolic and parabolic turbulence of 0.7
- Output frequency is set at 5 minutes

5.1.6 Model Assumptions and Limitations

The hydraulic model is limited by the quality, density, and accuracy of each data input and how the information is parameterized by the model. A few notable limitations of the hydraulic model are summarized below:

- The model assumes constant flow resistance across flow depths. In reality, at lower-flow depth, friction is a larger component of fluid motion.
- The model is fixed bed, all features are static. In reality, at flood stage, aggradation and degradation create pools and gravel bars and change the channel morphology.
- The hydraulic model does not account for infiltration loss or hyporheic inflow.
- Due to changes in the proposed alignment, the existing- and proposed-conditions alignment stationing differ throughout the model domain. See Appendix D for alignment comparisons.

5.2 Existing Conditions

The existing-conditions model was run for the 2-year; 100-year; 500-year; and projected 2080, 100-year MRIs. The average hydraulic results of the WSE, water depth, velocity, and shear stress are reported in Table 14 and the respective cross section locations are shown on Figure 43. Figure 44 and Figure 45 show the water surface profile and a typical section from the reference reach for the scenarios that were evaluated, respectively.

The water surface profile (Figure 44) shows a significant drop in the profile near station 14+80. In the field, this feature was identified as a large wood accumulation that creates a 3-foot step in the ground surface profile. The water surface slope both upstream and downstream of this step are similar at the 2-year event. Both profiles show long reaches of near-uniform slope separated by small periodic steps in the water surface.

The cross section on Figure 45 is just upstream of the wood accumulation step. Figure 45 is representative of the natural channel and reference reach, but it is not a representative depiction of the design. This figure shows the 2-year flood contained within the channel banks, and larger floods activating floodplain flow paths. The existing culvert across SR 3 is undersized at flows over the 2-year MRI, resulting in the culvert being submerged (pressure flow) and creating backwater conditions approximately 125 feet upstream of the crossing (Figure 46).

Figure 46 and Figure 47 also highlight the confinement of the channel downstream of the crossing as compared to upstream of the crossing. This difference reflects the available upstream floodplain.

At the 100-year MRI, average channel velocities range from 8 fps in the reference reach to 2.5 fps at the inlet the SR 3 crossing (WDFW ID 991242). Table 15 reports average velocities at the 100-year MRI throughout a variety of locations. Velocity in the main channel varies by roughly a factor of three. Velocity is highest, up to 8 fps, where the channel is confined and oversteps in the profile (wood accumulation and other step formers), but in the runs, flow velocity is much lower where the floodplain is engaged. Additional existing-condition model results are in Appendix H.

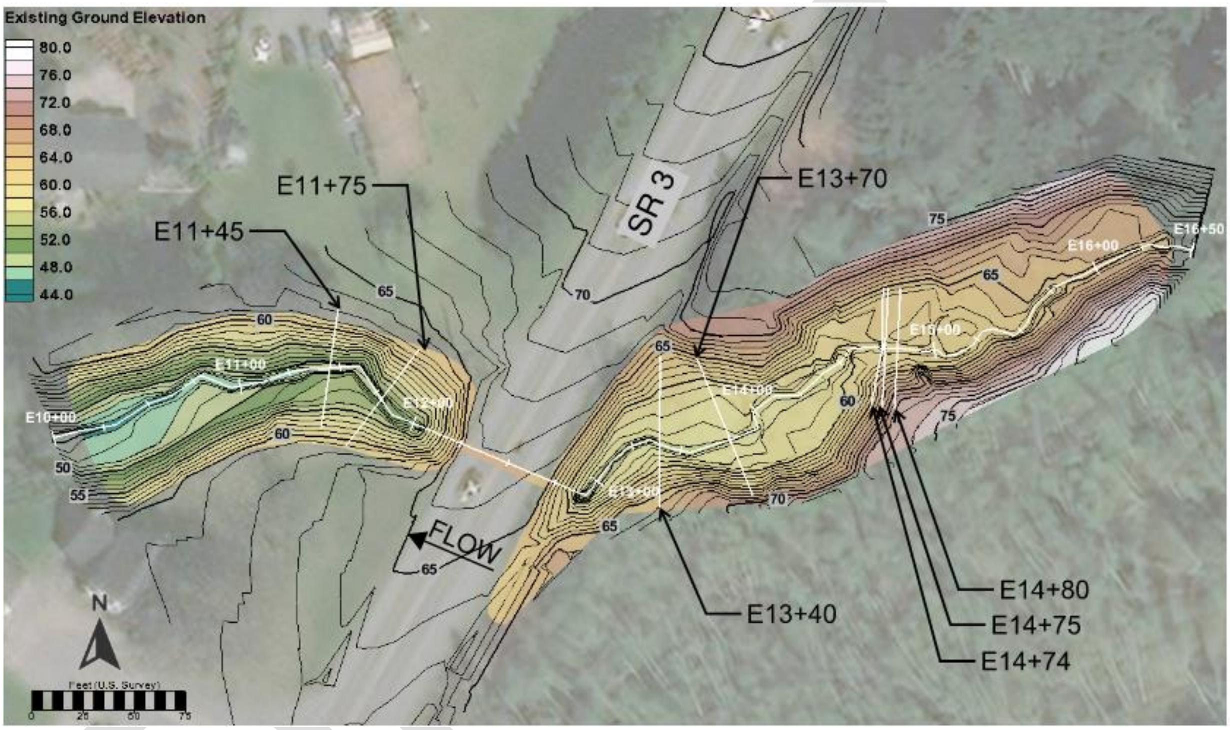
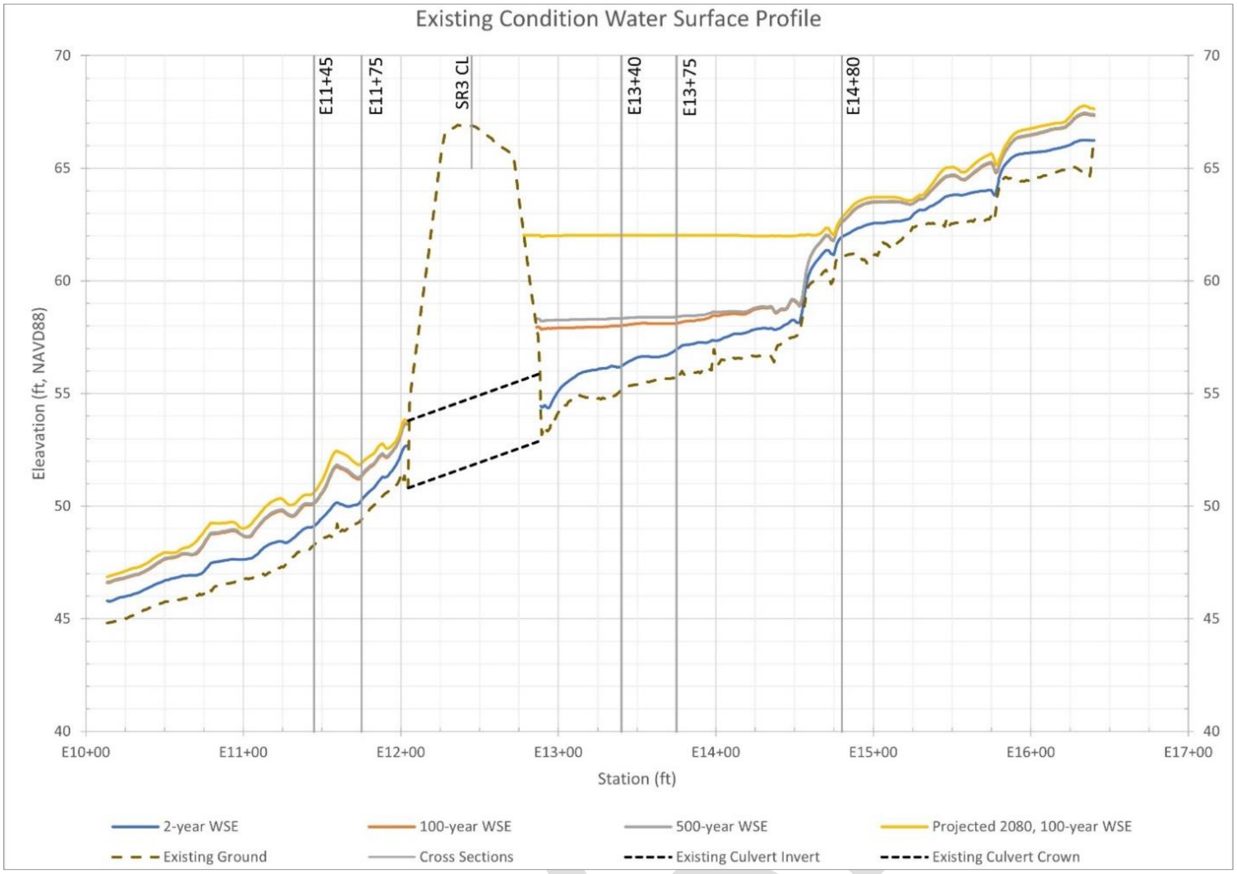


Figure 43: Locations of cross sections used for results reporting

Table 14: Average main channel hydraulic results for existing conditions

Hydraulic parameter	Cross section	2 year	100 year	100 Year 2080	500 year
Average WSE (ft)	E14+80	62.0	62.7	63.0	62.7
	E14+75	61.5	62.1	62.3	62.1
	E14+74	61.2	61.9	62.1	61.9
	E13+75	57.0	58.2	62.0	58.4
	E13+40	56.2	58.0	62.0	58.3
	Structure	N/A	N/A	N/A	N/A
	E11+75	50.6	51.7	52.2	51.8
	E11+45	49.1	50.1	50.6	50.2
Max depth (ft)	E14+80	0.9	1.6	1.8	1.6
	E14+75	0.6	1.2	1.4	1.3
	E14+74	1.2	1.8	2.1	1.8
	E13+75	1.2	2.4	6.3	2.6
	E13+40	1.2	3.0	7.0	3.3
	Structure	N/A	N/A	N/A	N/A
	E11+75	0.8	1.9	2.4	2.0
	E11+45	0.9	1.9	2.3	1.9
Average velocity (fps)	E14+80	3.3	5.0	4.7	5.1
	E14+75	4.6	6.6	7.2	6.6
	E14+74	3.9	6.4	6.8	6.4
	E13+75	2.7	3.3	0.8	2.7
	E13+40	3.5	2.9	0.8	2.4
	Structure	N/A	N/A	N/A	N/A
	E11+75	4.7	6.8	7.1	6.0
	E11+45	4.6	6.9	8.1	7.1
Average shear (lb/SF)	E14+80	1.0	1.7	1.6	1.7
	E14+75	2.2	3.1	3.4	3.2
	E14+74	1.7	2.9	2.9	2.9
	E13+75	0.7	0.6	0.0	0.4
	E13+40	1.0	0.4	0.0	0.3
	Structure	N/A	N/A	N/A	N/A
	E11+75	1.9	3.2	3.5	3.0
	E11+45	1.8	3.3	3.9	3.4

Main channel extents were approximated using breaks in topography and confirmed using the 2-year model extents.



Note: Not all cross section locations listed in Table 14 are shown in this figure.

Figure 44: Existing-conditions water surface profiles

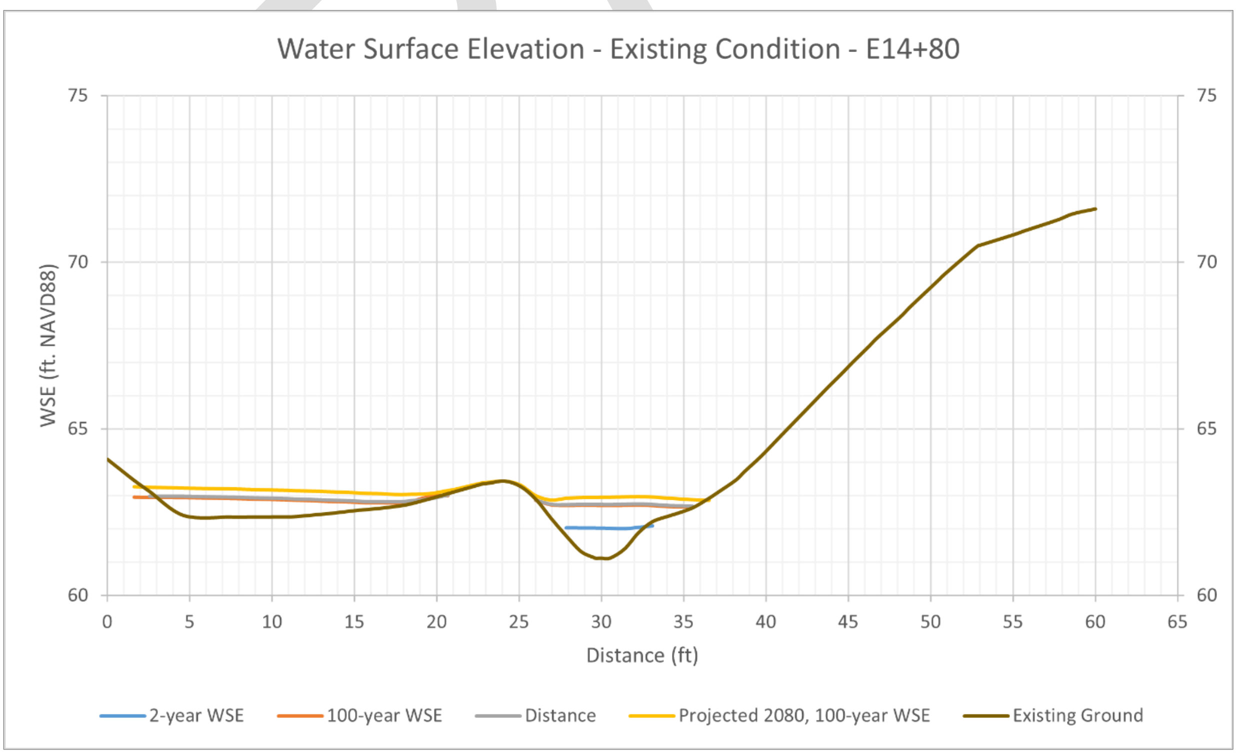


Figure 45: Typical upstream existing channel cross section (STA E14+80)

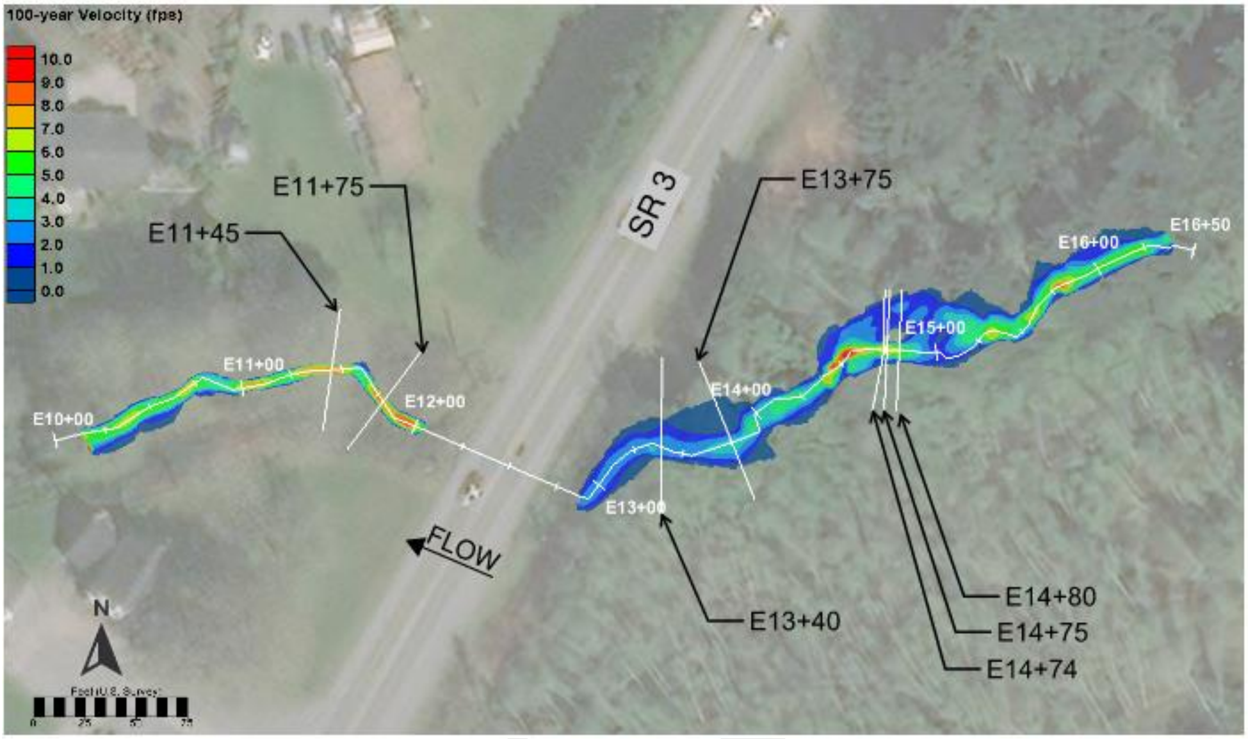


Figure 46: Overall existing-conditions 100-year velocity map with cross section locations

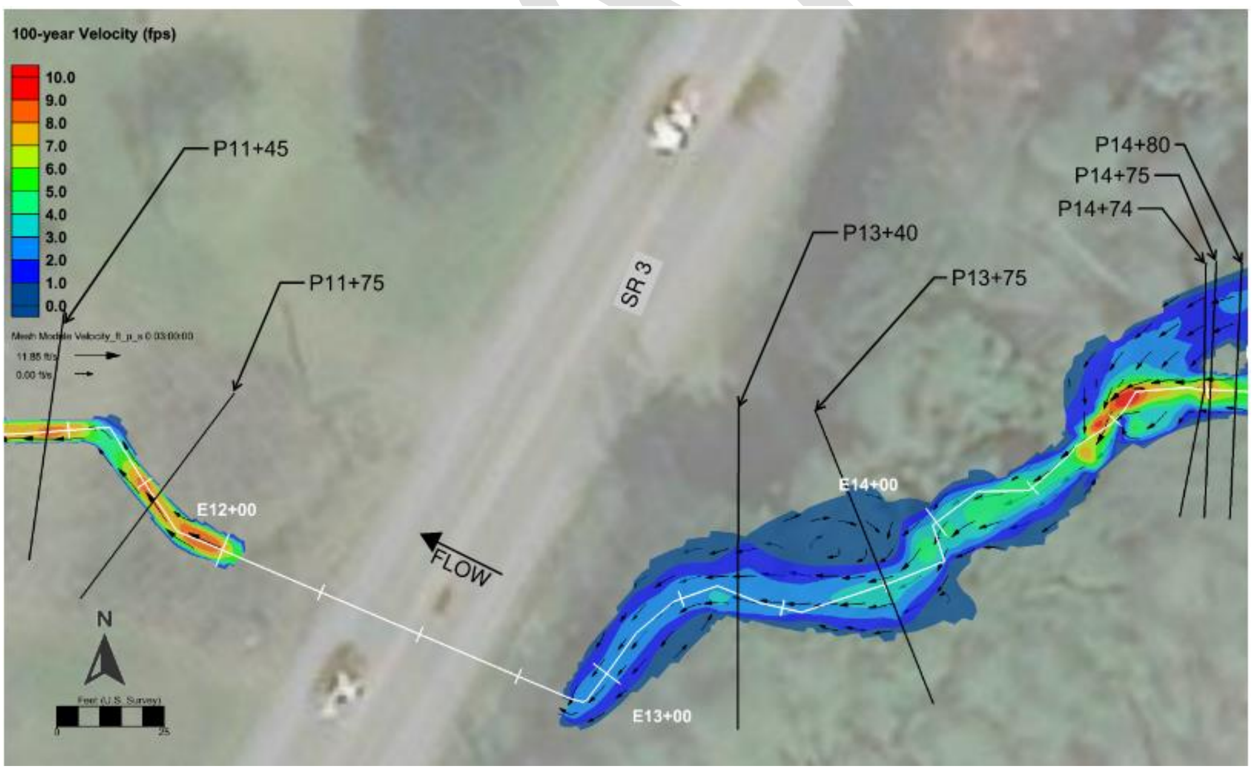


Figure 47: Existing-conditions 100-year velocity map at SR 3 crossing

Table 15: Existing-conditions average channel and floodplain velocities

Cross section location	Q100 average velocities tributary scenario (fps)		
	LOB	Main channel	ROB
E14+80	1.5	5.0	2.5
E14+75	1.5	6.6	1.8
E14+74	1.6	6.4	1.4
E13+75	0.4	3.3	1.6
E13+40	1.5	2.9	1.6
Structure	NA	NA	NA
E11+75	NA	6.8	NA
E11+45	0.0	6.9	0.0

Right overbank (ROB)/left overbank (LOB) locations were approximated using topographic grade breaks and then confirmed using the 2-year model results.

5.3 Natural Conditions

A natural-conditions hydraulic model was developed because the channel is unconfined when the FUR is calculated at the BFW measurement locations, see Section 2.7.2.1. The natural-condition scenario was performed by removing the highway prism from the existing-conditions terrain and interpolating between the upstream and downstream terrain. Figure 48 shows the terrain that was used to develop the natural-conditions model.

Figure 48: Natural-conditions terrain

The computational mesh and model extents for the natural-conditions model was developed using the same methods described in Section 5.1.2. The computational mesh developed covers the same land area and has a total of 24,909 elements defined in the mesh. Figure 49 and Figure 50 show the computational mesh and model extents for the natural-conditions model.

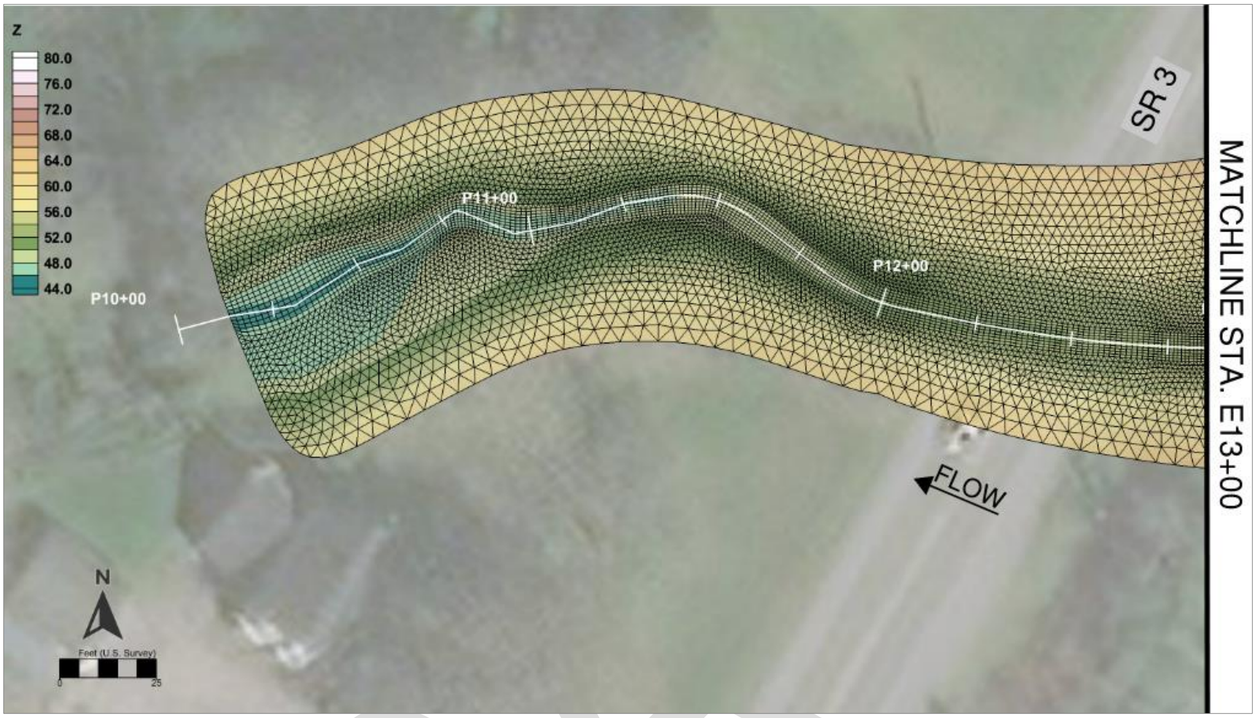


Figure 49: Western portion of natural-conditions computational mesh

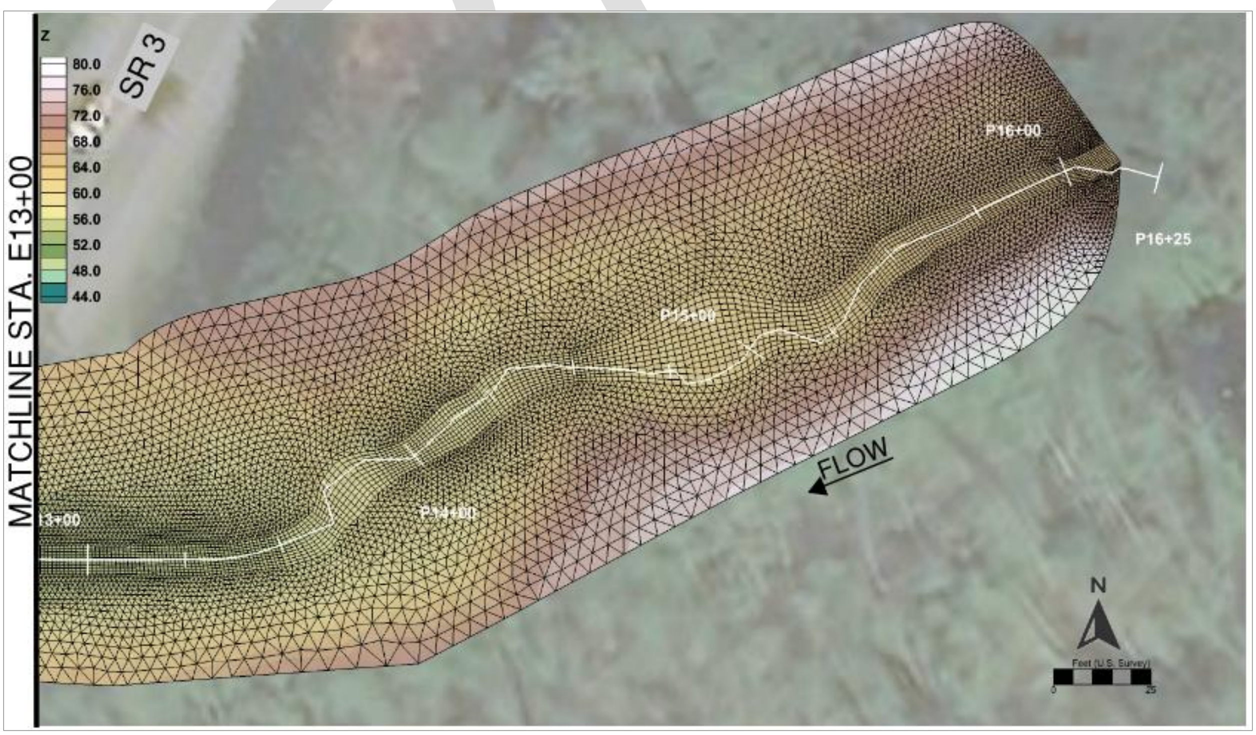


Figure 50: Eastern portion of natural-conditions computational mesh

The Manning's *n* values selected for the natural-conditions model match those that are shown for the existing-conditions mesh in Table 13 of Section 5.1.3. The materials coverage used for the natural-conditions model is shown on Figure 51.

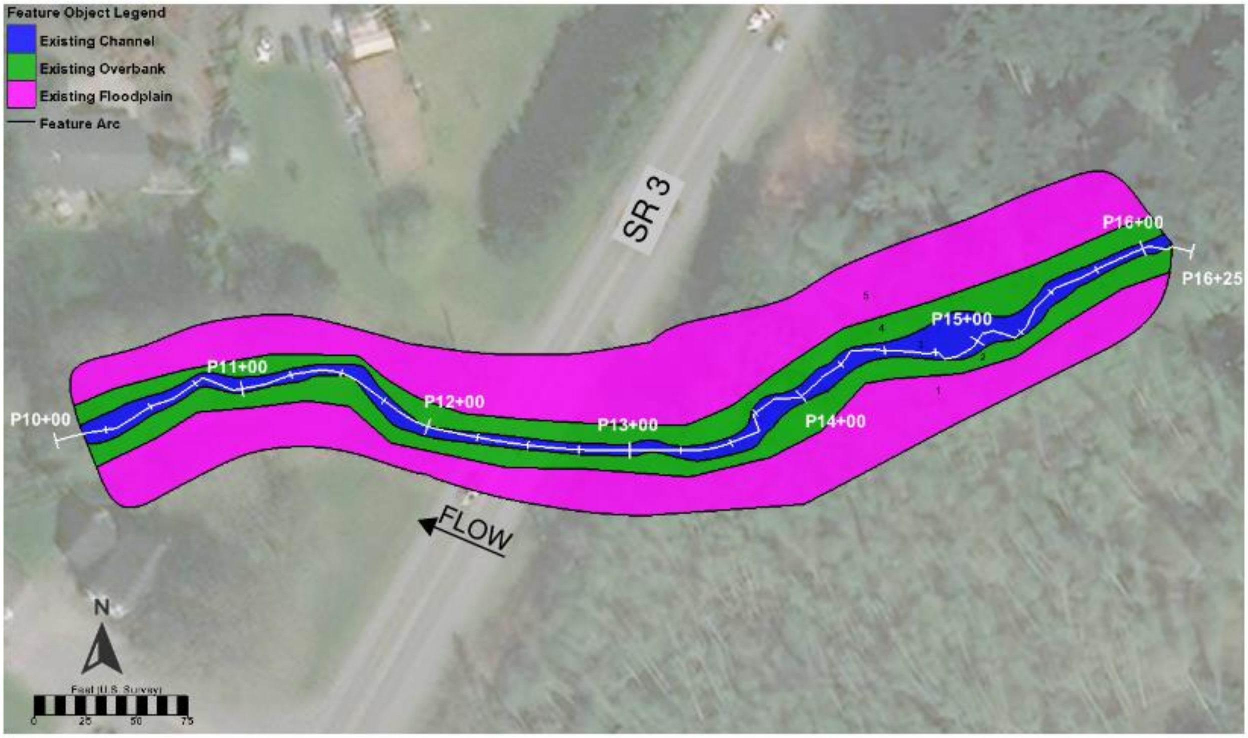


Figure 51: Natural-conditions materials coverage

The natural-conditions model represents a scenario approximating the UNT to Kinman Creek where there is no roadway prism or culvert for the tributary to pass through. Because of this, the boundary conditions match those of the proposed conditions. Figure 52 presents the natural-conditions model boundary conditions.

The results of the natural-conditions represent expected flow conditions upstream of the crossing that would occur naturally. The backwater produced in the existing-conditions model was eliminated in the natural-conditions model results. The results of the natural-conditions model are tabulated in Table 16, and the cross section locations are shown on Figure 53.

A water surface profile and typical section (Figure 54 and Figure 55, respectively) were produced for the MRIs evaluated in the natural-conditions model. This was to further represent the natural flow conditions that would be expected if the crossing were not present.

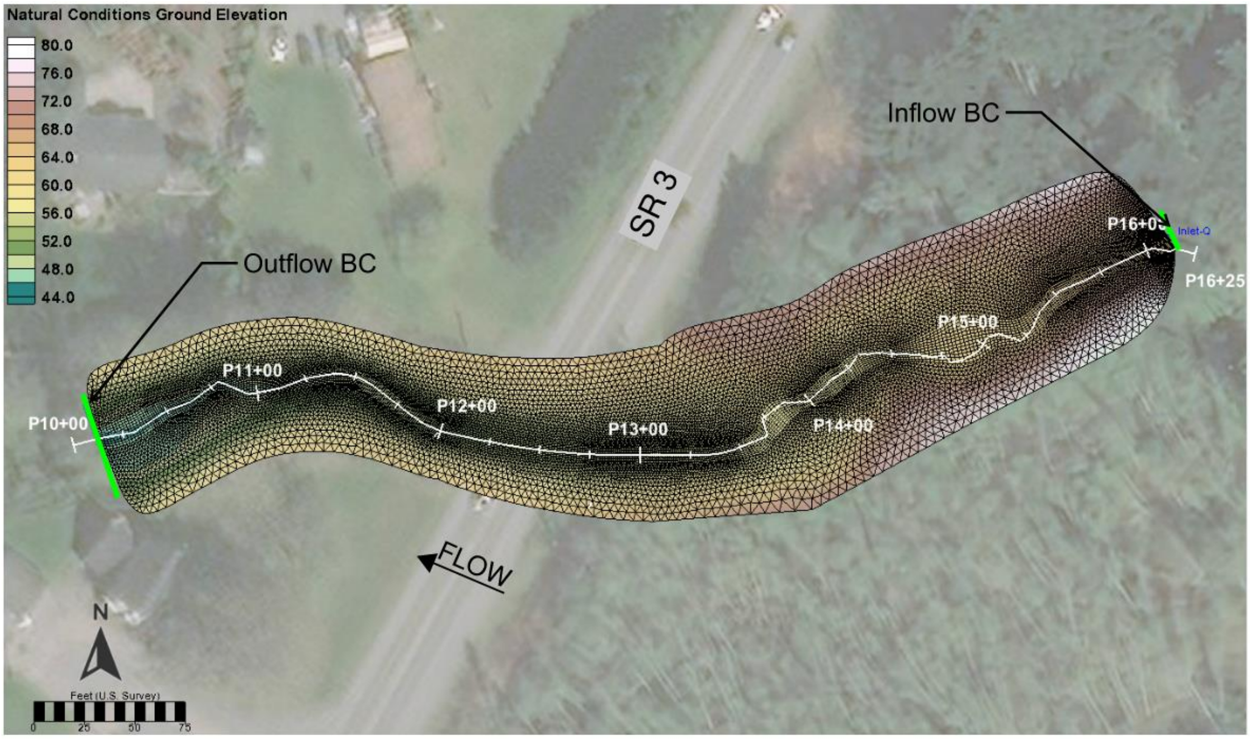


Figure 52: Natural-conditions boundary conditions

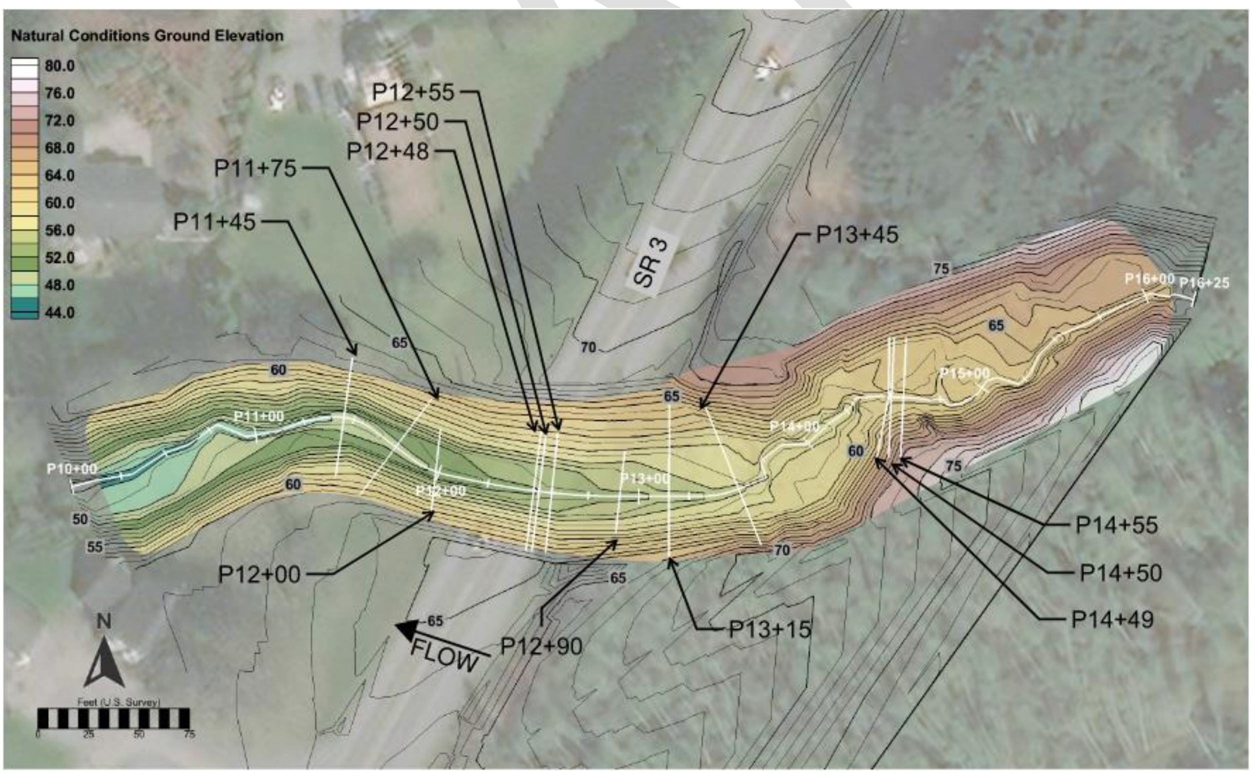
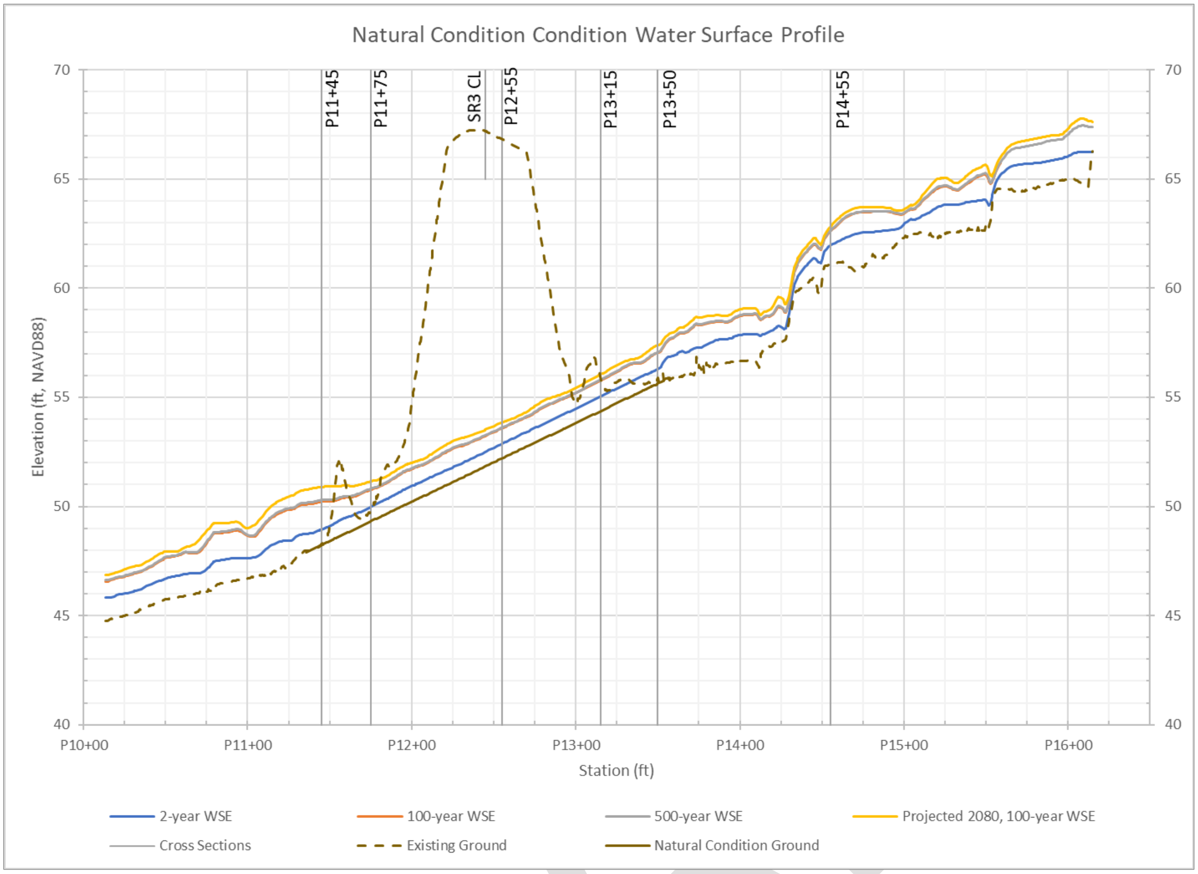


Figure 53: Natural-conditions cross section locations for reporting

Table 16: Main channel results for natural conditions

Hydraulic parameter	Cross section	2 year	100 year	100 Year 2080	500 year
Average WSE (ft)	P14+55	62.0	62.7	63.0	62.8
	P14+50	61.5	62.1	62.3	62.1
	P14+49	61.2	61.9	62.1	61.9
	P13+50	56.3	57.0	57.4	57.1
	P13+15	55.1	55.8	56.1	55.8
	P12+90	54.2	54.9	55.1	54.9
	P12+55	52.9	53.6	53.9	53.7
	P12+50	52.7	53.4	53.7	53.5
	P12+48	52.6	53.3	53.6	53.4
	P12+00	50.9	51.7	52.0	51.8
	P11+75	50.0	50.8	51.2	50.8
	P11+45	48.9	50.2	50.9	50.3
Max depth (ft)	P14+55	0.9	1.6	1.8	1.6
	P14+50	0.6	1.2	1.4	1.3
	P14+49	1.2	1.8	2.0	1.8
	P13+50	0.7	1.5	1.8	1.5
	P13+15	0.7	1.4	1.7	1.5
	P12+90	0.7	1.4	1.7	1.4
	P12+55	0.7	1.4	1.6	1.4
	P12+50	0.7	1.4	1.7	1.4
	P12+48	0.7	1.4	1.7	1.4
	P12+00	0.7	1.5	1.8	1.6
	P11+75	0.7	1.5	1.8	1.5
	P11+45	0.8	2.0	2.7	2.1
Average velocity (fps)	P14+55	3.3	5.0	4.7	4.7
	P14+50	4.6	6.5	7.2	6.6
	P14+49	4.4	6.3	6.9	6.4
	P13+50	3.7	6.2	6.2	6.2
	P13+15	3.3	5.9	6.7	6.0
	P12+90	3.5	5.7	6.5	5.8
	P12+55	3.5	5.7	6.4	5.8
	P12+50	3.4	5.7	6.3	5.7
	P12+48	3.4	5.7	6.3	5.8
	P12+00	3.1	5.3	6.1	5.4
	P11+75	3.3	5.7	6.1	5.7
	P11+45	3.4	4.3	4.2	4.3
Shear Stress (psf)	P14+55	1.0	1.7	1.6	1.6
	P14+50	2.2	3.1	3.4	3.1
	P14+49	1.9	2.9	3.0	2.9
	P13+50	1.4	2.4	2.1	2.4
	P13+15	1.1	2.4	2.9	2.4
	P12+90	1.1	2.2	2.7	2.3
	P12+55	1.1	2.1	2.5	2.2
	P12+50	1.1	2.0	2.3	2.1
	P12+48	1.1	2.0	2.3	2.1
	P12+00	1.2	2.3	2.8	2.4
	P11+75	1.0	1.9	2.0	1.9
	P11+45	1.1	1.1	1.0	1.1



Note: Not all cross section locations mentioned in Table 16 are shown in this figure.

Figure 54: Natural-conditions water surface profile

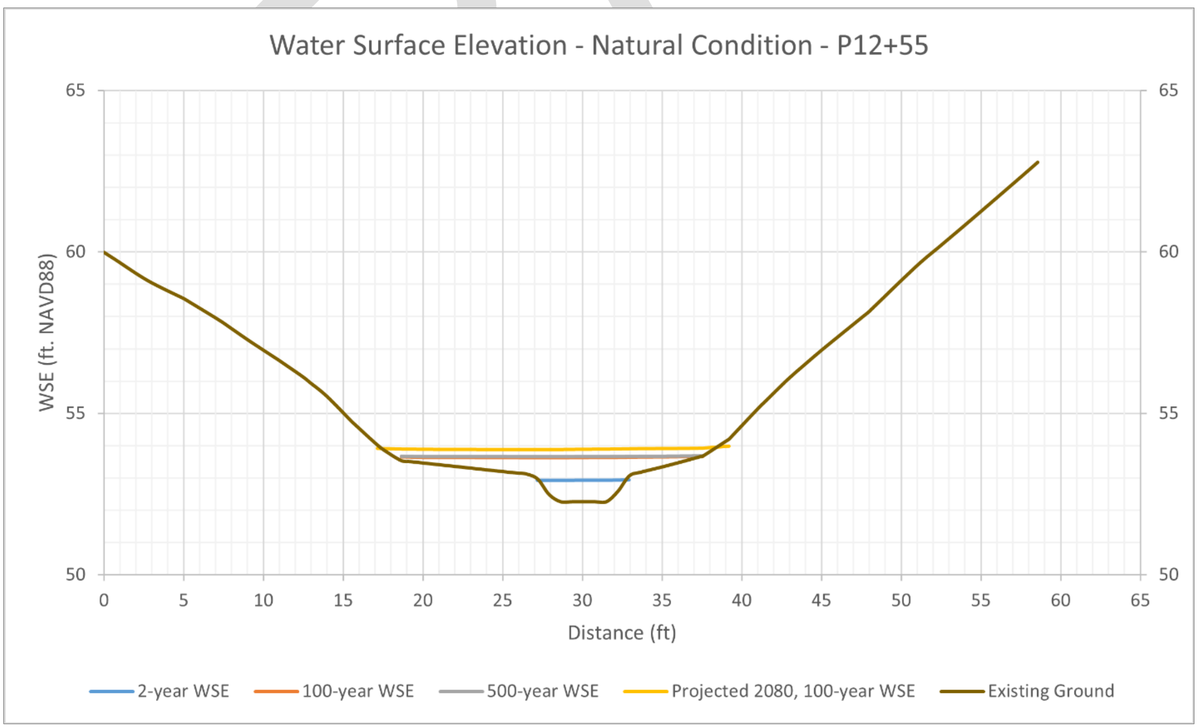


Figure 55: Natural-conditions typical cross sections (Sta. P12+55)

Due to the constriction of the undersized culvert being removed from the crossing, velocities across all flows evaluated increased through the reach. The resulting 100-year velocities are shown on Figure 56 and Figure 57, and the average main channel and floodplain velocities are tabulated in Table 17.

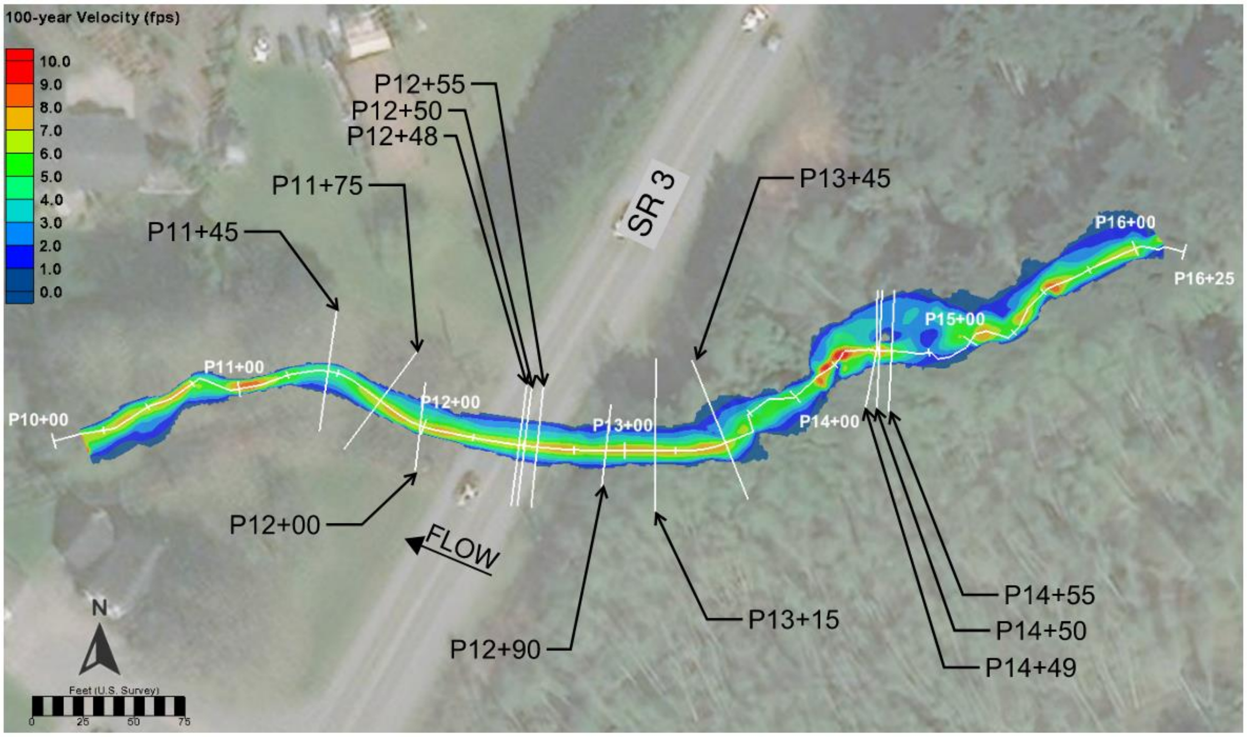


Figure 56: Overall natural-conditions 100-year velocity results

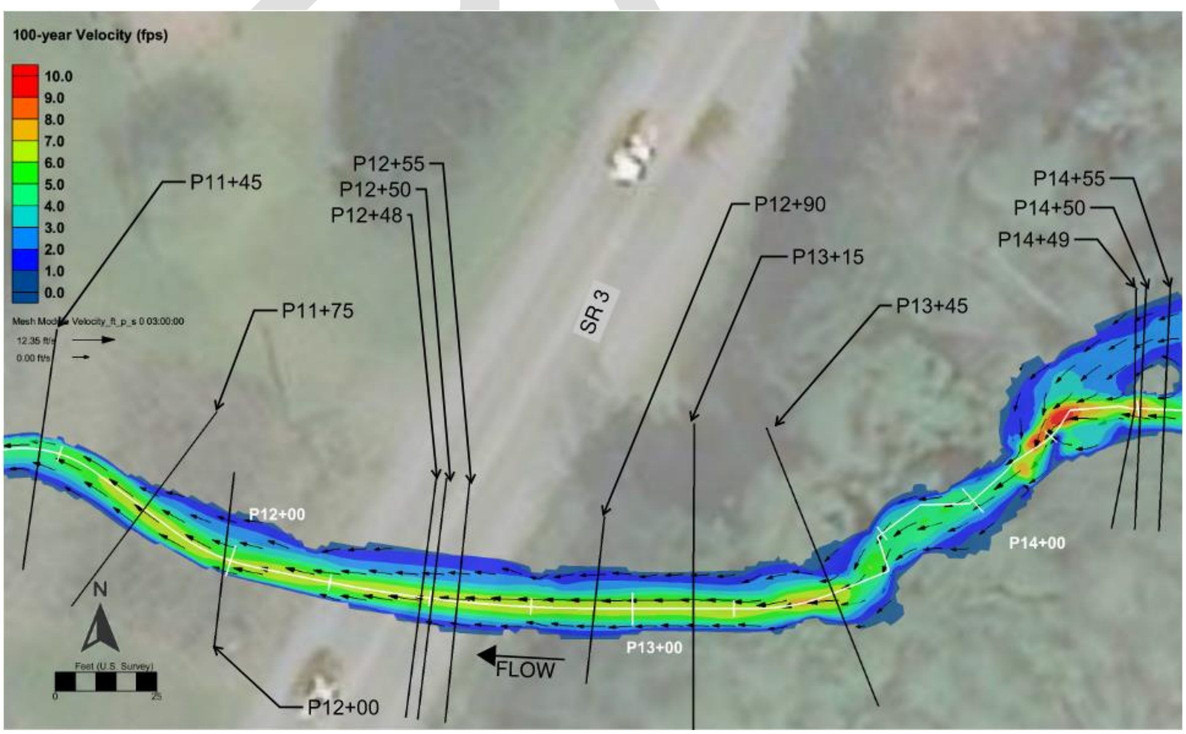


Figure 57: Natural-conditions 100-year velocity results at SR 3 crossing

Table 17: Natural-conditions average channel and floodplain velocities

Cross section location	Q100 average velocities (fps)			2080 Q100 average velocity (fps)		
	LOB	Main channel	ROB	LOB	Main channel	ROB
P14+55	1.6	5.0	2.5	2.1	4.7	3.0
P14+50	1.7	6.5	1.7	2.2	7.2	3.6
P14+49	1.5	6.3	1.3	2.4	6.9	3.3
P13+50	1.0	6.2	3.4	1.8	6.2	3.8
P13+15	2.0	5.9	2.2	2.4	6.7	3.1
P12+90	2.0	5.7	2.0	2.7	6.5	2.7
P12+55	2.2	5.7	1.7	2.9	6.4	2.3
P12+50	2.1	5.7	2.0	2.8	6.3	2.4
P12+48	2.1	5.7	1.9	2.8	6.3	2.5
P12+00	2.4	5.3	0.4	3.2	6.1	2.9
P11+75	1.6	5.7	2.5	2.3	6.1	4.2
P11+45	NA	4.3	1.9	1.1	4.2	2.3

ROB/LOB locations were approximated using topographic grade breaks and then confirmed using the 2-year model results.

5.4 Proposed Conditions: 18-foot Minimum Hydraulic Width

The hydraulic width is defined as the width perpendicular to the channel beneath the proposed structure that is necessary to convey the design flow and allow for natural geomorphic processes. The hydraulic modeling assumes vertical walls at the edge of the minimum hydraulic width unless otherwise specified. See Section 4.2.2 for a description of how the minimum hydraulic width was determined.

The proposed-conditions model provided results for the 2-year; 100-year; 500-year; and projected 2080, 100-year MRIs. The proposed-conditions model results showed that the channel performed similarly to the existing conditions in the reference reach. Table 18 shows the average WSE, depth, velocity, and shear stress results from the proposed-conditions model for the MRIs listed above. Slight variations in velocity and shear stress can be seen in results from the model outside the area of influence of the structure (above station P14+20). These variations are minor and are due to slight changes in the computational mesh used for the existing, natural, and proposed conditions. Figure 58 shows the cross sections that were used for the evaluation.

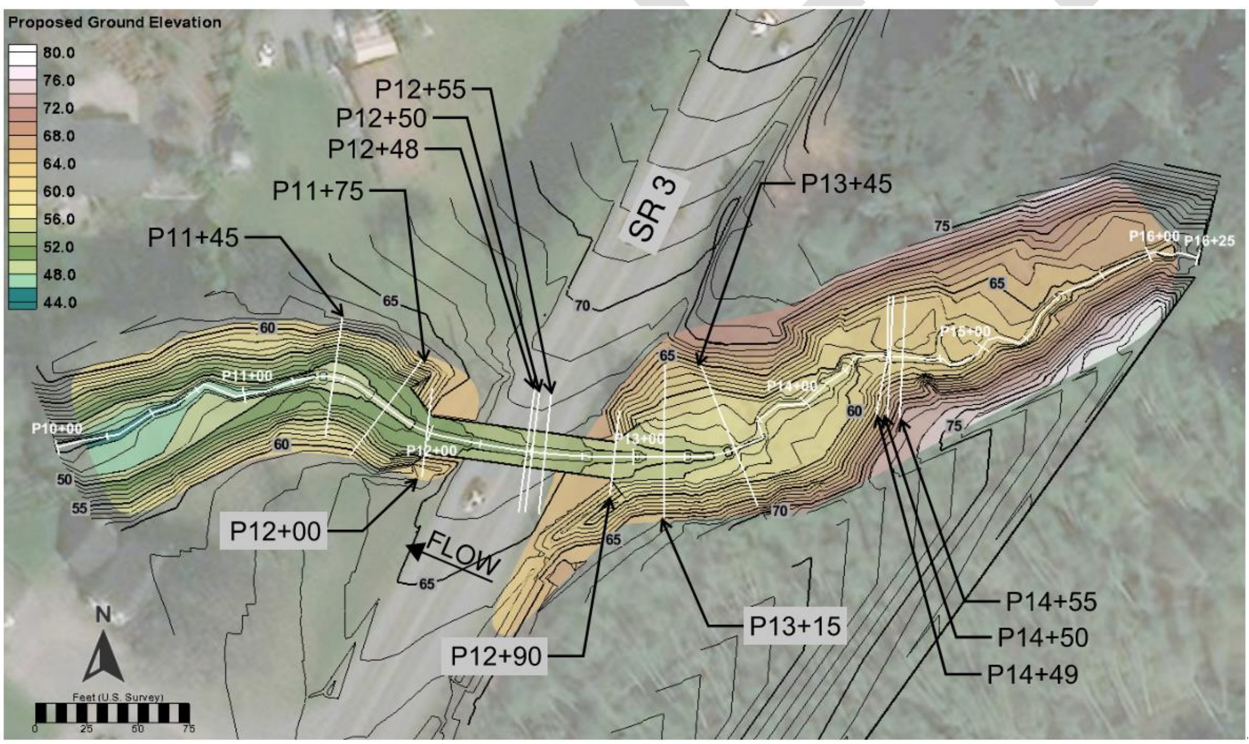


Figure 58: Locations of cross sections on proposed alignment used for results reporting

Table 18: Average main channel hydraulic results for proposed conditions

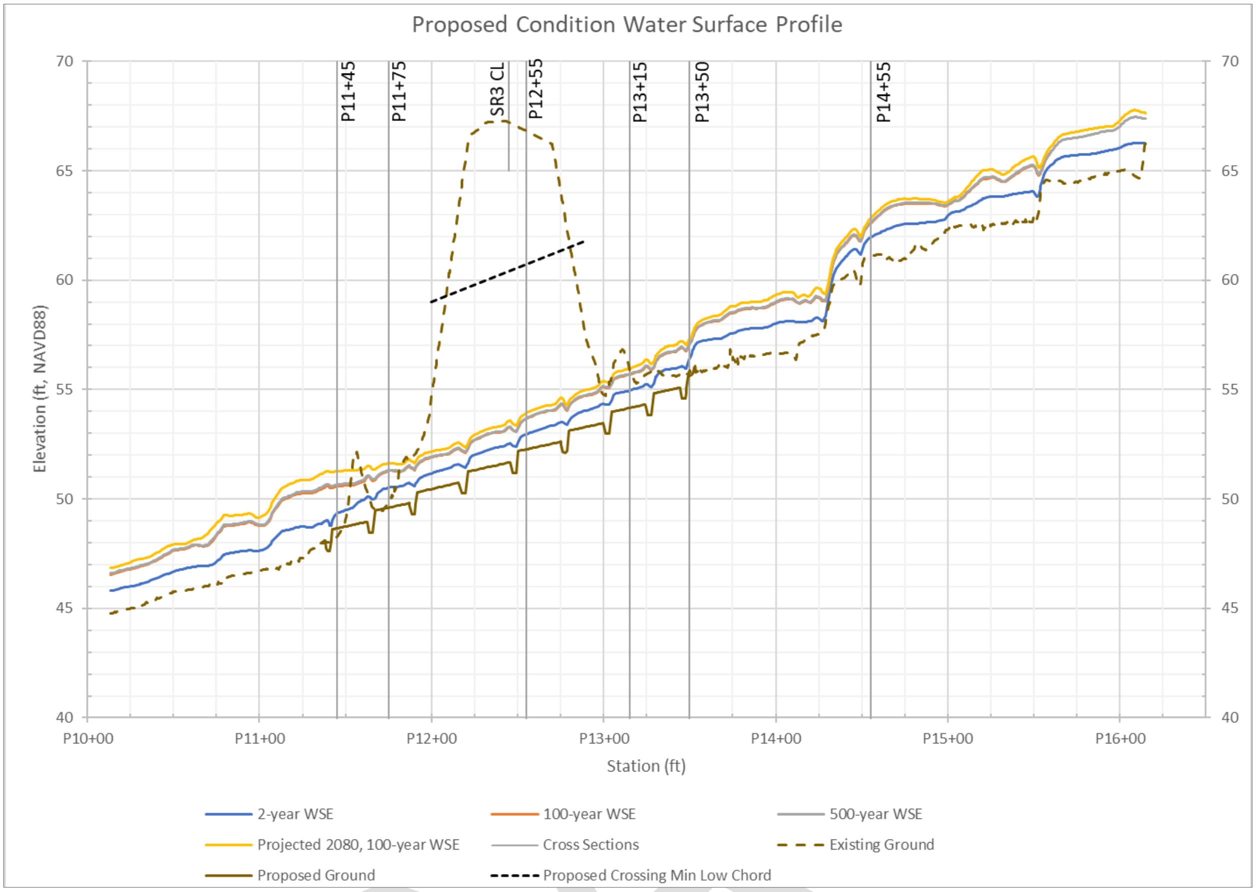
Hydraulic parameter	Cross section	2 year	100 year	100 year 2080	500 year
Average WSE (ft)	P14+55	62.0	62.7	63.0	62.7
	P14+50	61.5	62.1	62.3	62.1
	P14+49	61.3	61.9	62.1	61.9
	P13+50	56.4	57.0	57.3	57.1
	P13+15	54.9	55.7	56.0	55.7
	P12+90	54.1	54.7	55.0	54.8
	P12+55 (Structure)	53.0	53.7	54.0	53.8
	P12+50 (Structure)	52.7	53.3	53.5	53.3
	P12+48 (Structure)	52.4	53.1	53.4	53.1
	P12+00	51.2	51.9	52.2	51.9
	P11+75	50.5	51.3	51.6	51.3
	P11+45	49.3	50.6	51.3	50.7
Max depth (ft)	P14+55	0.9	1.6	1.8	1.6
	P14+50	0.7	1.2	1.4	1.3
	P14+49	1.2	1.8	2.0	1.8
	P13+50	0.8	1.5	1.7	1.5
	P13+15	0.8	1.5	1.8	1.6
	P12+90	0.8	1.4	1.7	1.5
	P12+55 (Structure)	0.7	1.5	1.7	1.5
	P12+50 (Structure)	0.4	1.1	1.4	1.1
	P12+48 (Structure)	1.2	1.9	2.2	2.0
	P12+00	0.7	1.5	1.7	1.5
	P11+75	0.9	1.7	2.1	1.7
	P11+45	0.7	1.9	2.6	2.0
Average velocity (fps)	P14+55	3.3	5.0	4.7	5.0
	P14+50	4.6	6.6	7.2	6.7
	P14+49	3.8	6.4	6.9	6.4
	P13+50	2.9	5.0	5.3	5.0
	P13+15	2.6	4.7	5.3	4.8
	P12+90	2.8	5.2	5.8	5.3
	P12+55 (Structure)	2.9	5.2	5.9	5.3
	P12+50 (Structure)	3.7	6.6	7.2	6.6
	P12+48 (Structure)	2.5	5.6	6.4	5.7
	P12+00	3.1	5.2	5.9	5.3
	P11+75	2.4	4.3	4.7	4.3
	P11+45	3.3	3.3	3.0	3.3
Shear Stress (psf)	P14+55	1.0	1.7	1.6	1.7
	P14+50	2.2	3.1	3.4	3.2
	P14+49	1.5	2.9	3.0	2.9
	P13+50	5.1	9.7	10.3	9.8
	P13+15	0.5	0.9	1.1	1.0
	P12+90	0.6	1.2	1.4	1.2
	P12+55 (Structure)	0.6	1.2	1.4	1.2
	P12+50 (Structure)	2.5	4.2	4.6	4.2
	P12+48 (Structure)	1.1	2.8	3.3	2.8
	P12+00	0.7	1.2	1.4	1.2
	P11+75	0.9	2.0	2.3	2.1
	P11+45	1.4	1.0	0.7	1.0

Due to the proposed step-pool-glide design, the channel and floodplain through the crossing and the reference reach were directly compared to determine the performance of the design. The intent of the design was to mimic the conditions found in the reference reach. To make this determination, sections at Stations P12+48 (pool), P12+50 (step), and P12+55 (riffle) through the crossing were compared directly to sections at Stations P14+49 (pool), P14+50 (step), and P14+55 (glide) in the reference reach. The results in Table 18 show that the reference reach and the proposed step-pool-glide morphology perform similarly at all flow conditions.

When observing average main channel velocity at the 2-year MRI through the crossing, velocities generally do not exceed 5 fps. This metric is the maximum allowable velocity by the WCDG (Barnard et al. 2013) for a structure of this size.

Average shear stress within the proposed project area is artificially high in areas. This is due to the incorporation of LWM, half-channel coarse bands, and forcing elements in the model that are represented as increased roughness. Increased roughness has the effect of increasing water surface, which drives shear stress as the depth-slope product.

The proposed-condition water surface profile was also used to determine the performance of the proposed design. Figure 59 shows these results for the scenarios that were evaluated. The WSE drop was measured for each scenario. It was seen that under all flow conditions evaluated, the water surface drop ranged between 0.2 to 0.5 foot. These results were measured between the highest WSE at the top of the step to the lowest WSE in the pool. These results are likely overexaggerated in the model due to the individual calculations performed at each node representing the proposed step-pool morphology. The steep slopes as the step transitions to a pool accelerates flow and drops the WSE below the tailwater WSE. While this may occur locally at lower flows, the design team expects that the pool water elevation would be the elevation of the pool tailwater.



Note: Not all cross section locations mentioned in Table 18 are shown in this figure.

Figure 59: Proposed-conditions water surface profiles

A typical glide section was produced (Figure 60) in the crossing to represent the hydraulic performance of the design as it relates to the reference reach. Across all MRIs, the flow conditions (depth and velocity) perform similarly to the reference reach. Although Jacobs did not perform a sensitivity analysis using a wider structure, it can be assumed that any benefit from wider than 18 feet would have a negligible improvement on performance due to the 100-year WSE being less than a foot deep at the highest point of SBM in the cross section.

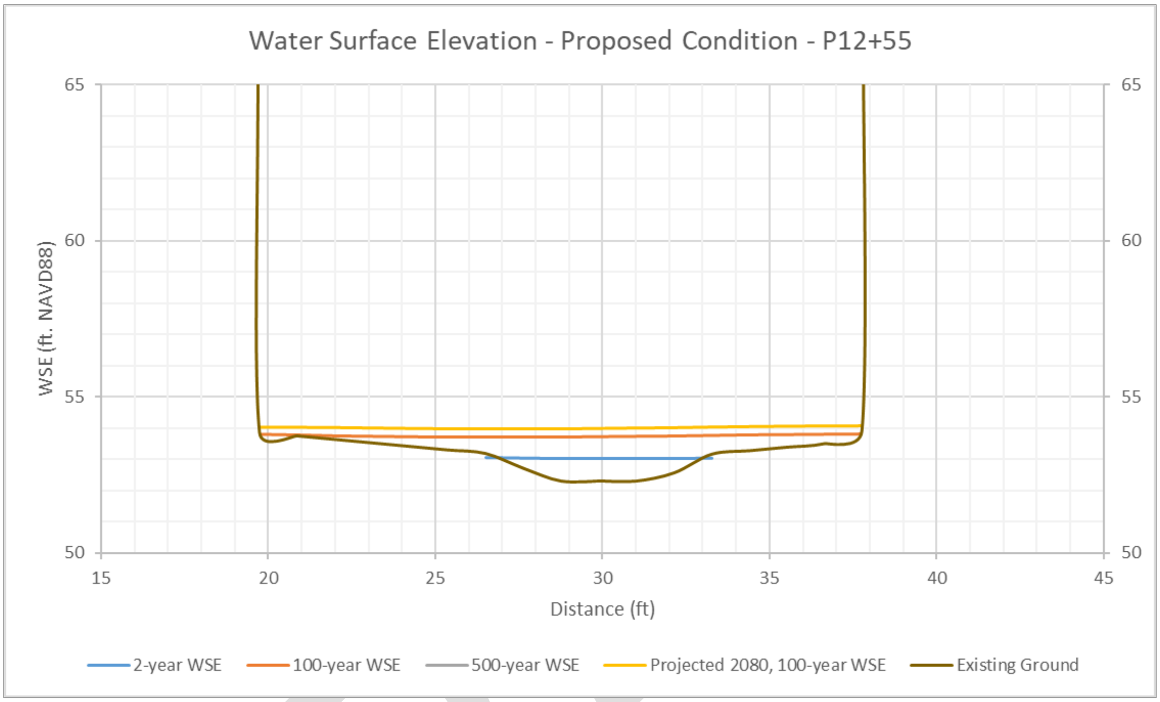


Figure 60: Typical section through proposed structure (STA P12+55)

The velocity results for the proposed-conditions model show the performance of the crossing successfully mimics the results seen in the reference reach. Figure 61 and Figure 62 show velocity results at the 100-year MRI. While results show an increase in velocities through the crossing when compared to the existing conditions, when compared to the reference reach, the performance is similar—maximum velocities reach around 7 fps. Furthermore, downstream of the crossing, velocities are significantly reduced when compared to the existing condition. This reduction in velocity will likely reduce the likelihood of any downcutting propagating into the crossing.

Figure 61 also shows cross sections where results were tabulated in Table 19. Table 19 shows the results comparing average channel and floodplain velocities between the proposed 100-year MRI and the projected 2080, 100-year MRI. The performance through the crossing is similar, with main channel velocities for the projected 2080, 100-year MRI staying within 12.5 percent of the current flow estimate of the 100-year MRI.

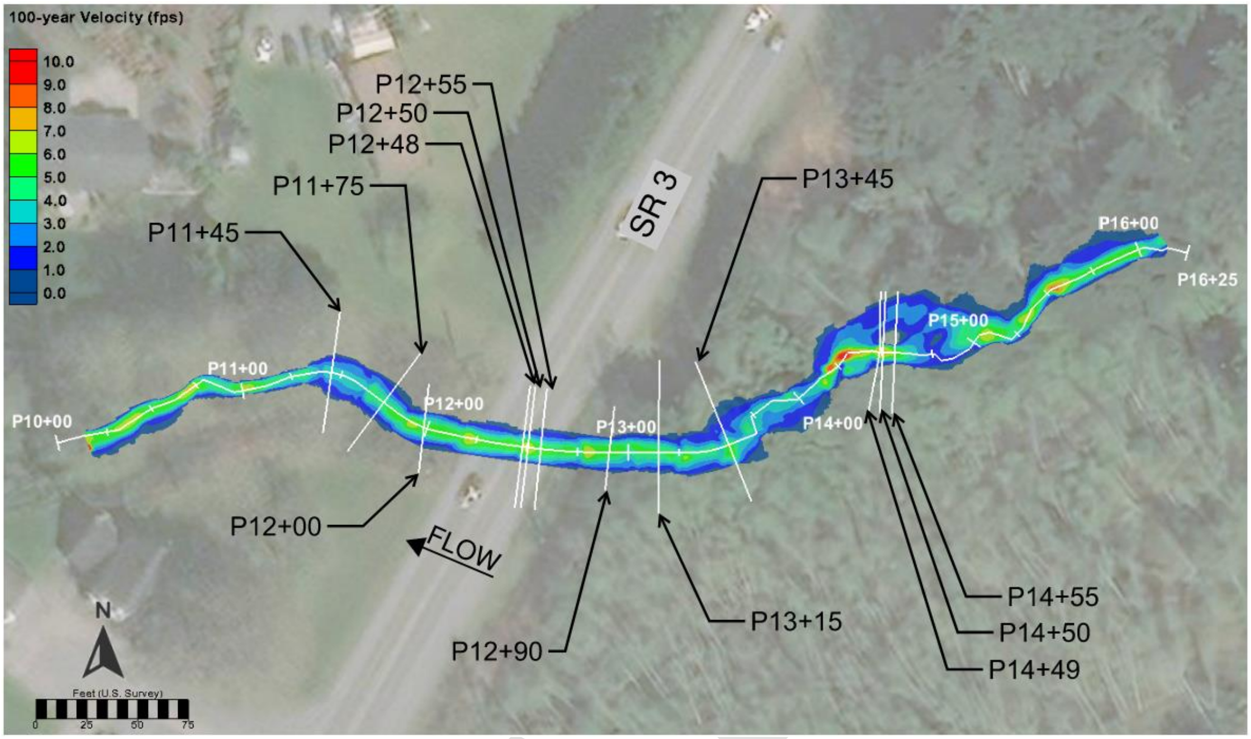


Figure 61: Overall proposed-conditions 100-year velocity map

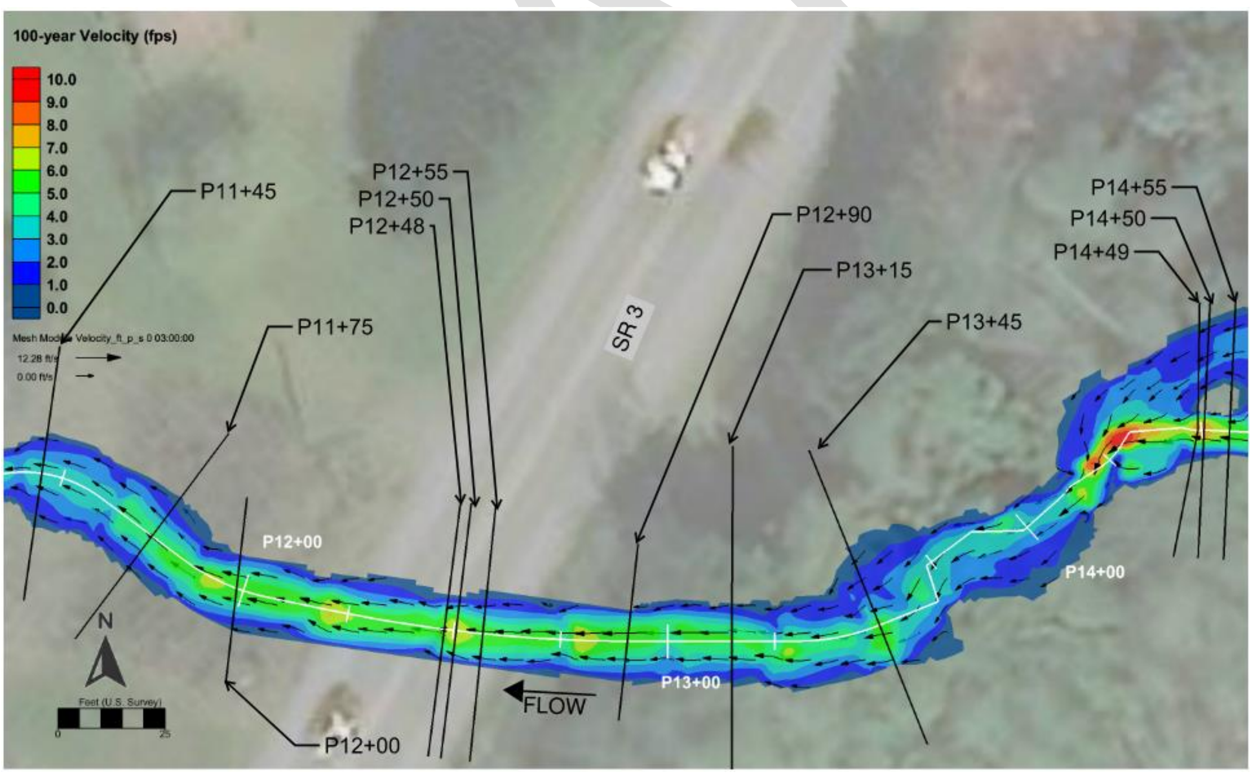


Figure 62: Proposed-conditions 100-year velocity map at SR 3 crossing

Table 19: Proposed-conditions average channel and floodplain velocities

Cross section location	Q100 average velocities (fps)			2080 Q100 average velocity (fps)		
	LOB	Main channel	ROB	LOB	Main channel	ROB
P14+55	1.6	5.0	2.6	2.1	4.7	3.0
P14+50	1.6	6.6	1.8	2.2	7.2	2.9
P14+49	1.5	6.4	1.6	2.4	6.9	3.1
P13+50	1.4	5.0	4.6	2.5	5.3	4.4
P13+15	2.2	4.7	2.0	2.5	5.3	3.1
P12+90	3.2	5.2	2.4	3.9	5.8	3.0
P12+55 (Structure)	1.7	5.2	3.0	2.8	5.9	3.8
P12+50 (Structure)	2.7	6.6	3.3	3.4	7.2	4.6
P12+48 (Structure)	2.5	5.6	2.8	3.4	6.4	4.4
P12+00	2.5	5.3	2.1	2.9	5.9	2.7
P11+75	1.5	4.3	1.7	1.5	4.7	2.7
P11+45	1.6	3.3	1.3	1.8	3.0	1.5

ROB/LOB locations were approximated using grade breaks and confirmed using the 2-year flow results.

6 Floodplain Evaluation

As noted in Section 2.1, this project is within a special flood hazard area but not within a mapped FEMA floodplain, as shown in Appendix A. The area is designated as Zone A: areas subject to inundation by the 1-percent-annual-chance flood event without base flood elevation (FEMA 2017). The existing project and expected proposed project conditions were evaluated to determine whether the project would cause a change in flood risk.

6.1 Water Surface Elevations

Generally, WSEs decrease across the model domain when comparing the existing and proposed conditions. Figure 63 shows the water surface profile comparing the 100-year MRI results for existing and proposed conditions. When looking at the water surface profile, the existing and proposed WSEs converge approximately 125 feet upstream of the existing crossing.

Figure 64 shows a comparison of the existing and proposed model results at the 100-year MRI. Figure 64 shows that there are areas of small, local rises (<0.3 foot upstream and <0.5 foot downstream), likely due to the placement of LWM and increased conveyance. However, across the project area, WSEs decrease. These changes in WSE and inundation areas do not pose a risk to properties or infrastructure. This is due to the channel being contained within a valley which flows are not able to exit. A flood risk assessment will be developed during later stages of the design.

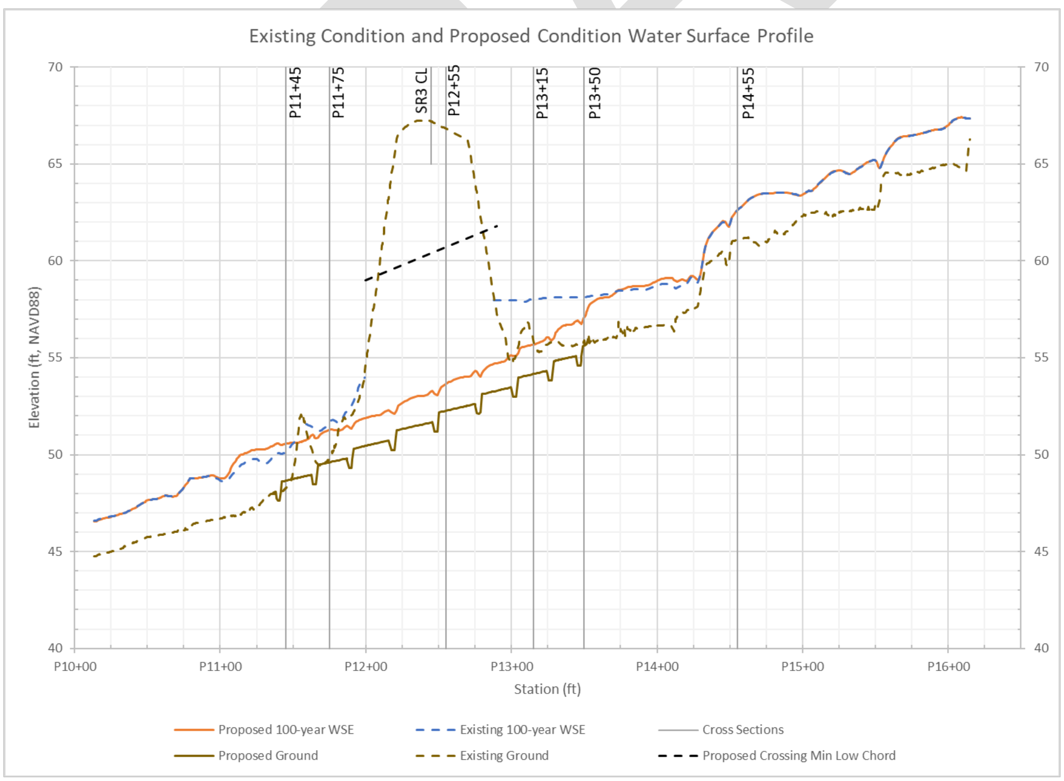


Figure 63: Existing- and proposed-conditions 100-year water surface profile comparison along proposed alignment

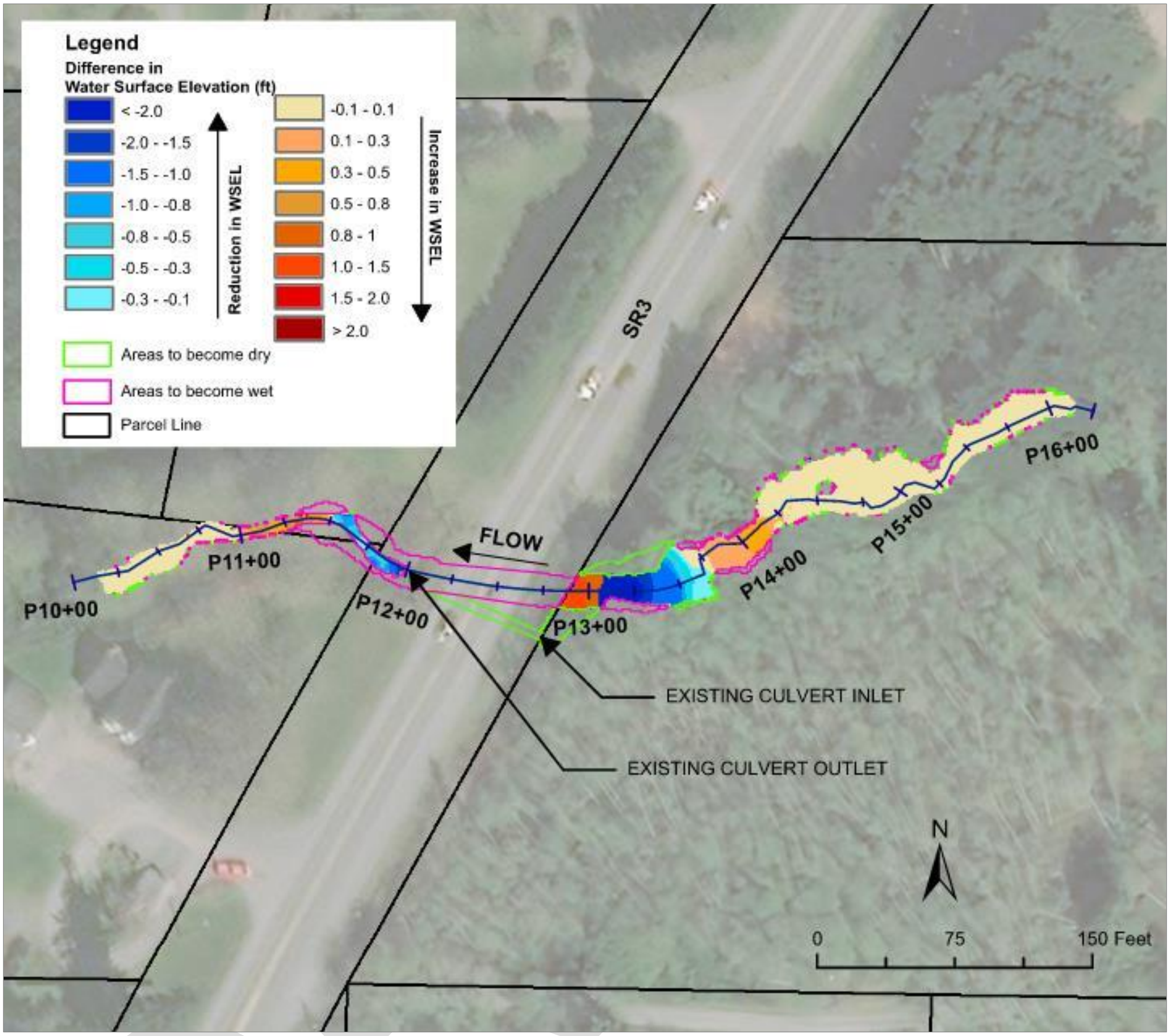


Figure 64: 100-year WSE change from existing to proposed conditions

7 Scour Analysis

For this preliminary phase of the project, the risk for lateral migration, potential for long-term degradation and evaluation of preliminary total scour are based on available data, including but not limited to the geotechnical scoping memorandum (WSDOT 2021b), Wolman pebble counts (Section 2.7.3), and proposed channel design concept (Appendix D). This evaluation is to be considered preliminary and is not to be taken as a final recommendation.

Using the results of the hydraulic analysis (Section 5.4), based on the recommended minimum hydraulic opening (18 feet) and considering the potential for lateral channel migration, preliminary scour calculations for the scour design flood and scour check flood were performed following the procedures outlined in *Evaluating Scour at Bridges* (HEC-18) (Arneson et al. 2012). For this analysis, the scour design flood is considered the event that produces the greatest depth of scour, the 2080, 100-year event (84 cfs). The scour check flood, as defined by WSDOT's *Hydraulics Manual* (2022a) is considered equivalent or larger than the design event, and therefore is also defined as the 2080, 100-year discharge. Additionally, the design team analyzed the 2-year (12 cfs), 100-year (54 cfs), and 500-year (57 cfs) events to investigate how other discharges influence scour at the site. Due to the relatively small difference in discharge magnitude between 12 cfs and 54 cfs, other intermediate flows (such as the 10-year, 25-year, or 50-year events) were not analyzed. The proposed design includes pools and glides to mimic the reference reach; scour depths are referenced to a depth below the lowest location of the thalweg profile at each pool.

Scour components considered in the analysis include the following:

- Long-term degradation
- Contraction scour
- Local scour

In addition to the three scour components listed above, the potential for lateral migration was assessed to evaluate total scour at the proposed highway infrastructure. These various scour components are discussed in the following sections.

7.1 Lateral Migration

The risk of lateral migration is moderate. Roughly 0.25-mile upstream, mass-wasting events have occurred, resulting in landslide deposits in the valley. These deposits represent a likely significant sediment source to the channel. Despite an intervening crossing between the deposits and the SR 3 crossing, a large flood event may mobilize sediments, creating transport-limited conditions (more sediment coming in than can be transported out). If significant deposition were to occur, the channel could avulse (suddenly change its alignment). This risk is likely greater than migration via gradual meander bend movement over time. Lateral migration to either side of the structure is assumed to be possible, and the design considers main channel scour occurring at the abutment wall.

WSDOT's Geotechnical Office provided a scoping memorandum (WSDOT 2021b) that included the log for Boring A-564P-22 (WSDOT 2022b), located on the downstream shoulder of SR 3 adjacent to the existing crossing. The boring classified soils below the fill layer (ESU 3b) as coarse-grained glacial deposits, with medium erodibility. The ESU 3b layer is roughly 25 deep, underlain by ESU 4, a fine-grained glacial clay layer. A non-erodible layer was not noted in the boring and the geologic mapping does not indicate a nearby hard control layer.

7.2 Long-term Degradation of the Channel Bed

The risk of long-term degradation at this site is considered moderate. The watershed longitudinal profile (Figure 65) is relatively straight, indicating neither excess deposition nor erosion. The projected slope (or equilibrium profile) is functionally the same as the existing profile, indicating neither aggradation nor degradation are likely. The proposed profile ties into existing conditions 75 feet downstream and 30 feet upstream of the existing culvert for continuity with the adjacent reaches. Additionally, the crossing will be actively engaged with the floodplain, providing a relief valve for sediment deposition. The downstream distance to base level control was determined as the location where proposed grading ties into the existing stream, 75 feet downstream. No other evidence of base level control was observed during field visits or noted in the geotechnical investigation (WSDOT 2021b, 2022b). A detailed assessment of the mass-wasting source should be conducted during final design and an assessment of long-term vertical channel change revisited at that point.

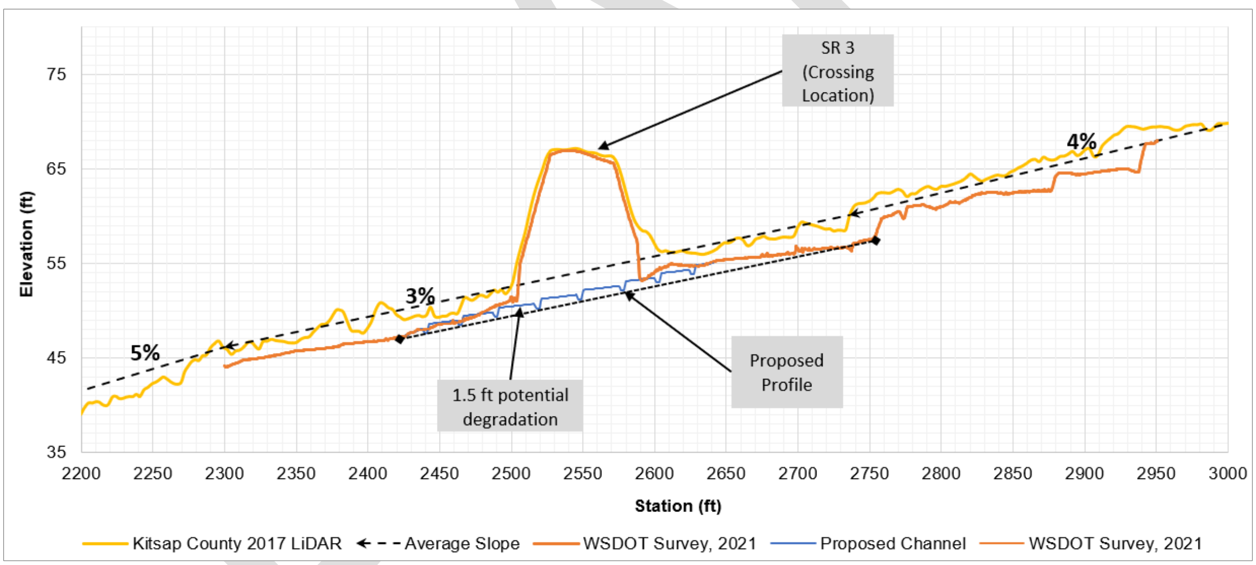


Figure 65: Potential long-term degradation through the proposed structure

A quantitative assessment of long-term degradation following guidance in HEC-20 (Lagasse et al. 2012) or the Hydraulic Design Series No. 6 (Richardson et al. 2001) was not performed because no evidence of the system being supply limited was observed. A maximum of 1.5 feet of potential long-term degradation will be carried forward as a design recommendation.

7.3 Contraction Scour

Contraction scour was evaluated through the proposed structure and computed following guidance from HEC-18 (Arneson et al. 2012). Scour was computed for both the main channel and overbank areas since Scour Condition 1c was present. Live bed conditions prevailed in the main channel and clear water on both overbank areas. The particle diameters used in the clear water equation are based on the surface Pebble Count 3 collected in the field for a glide (see Table 5 in Section 2.7.3), with a D_{50} of 15.2 millimeters. The approach arc was drawn at the closest distance upstream of the crossing prior to influence of the crossing. The width transporting sediment for the approach and contracted sections was defined based on the Critical Velocity Index (CVI) map, see Figure 66. The CVI was derived from a modified version of Equation 6.1 from HEC-18 and relates stream velocity to the mobility of the D_{50} of the streambed material (Arneson et al. 2012). Values over 1.0 on the CVI generally relate to live-bed scour conditions. The width of the approach arc transporting sediment is 9.4 feet, and the width of the contracted arc transporting sediment is 5.3 feet.

The clear water left and right overbank areas did not result in predicted scour. Following HEC-18 (Arneson et al. 2012) guidance for live bed conditions, both live bed and clear water contraction scour were calculated, and the lower of the two values recommended. The main channel live bed contraction scour results in zero predicted scour for both the design and check flood events (Figure 67). Live bed contraction scour for the 2-year event results in no general contraction scour, supporting the assertion that larger-flow events result in more contraction scour. No additional analysis to investigate intermediate scour-producing events was performed.

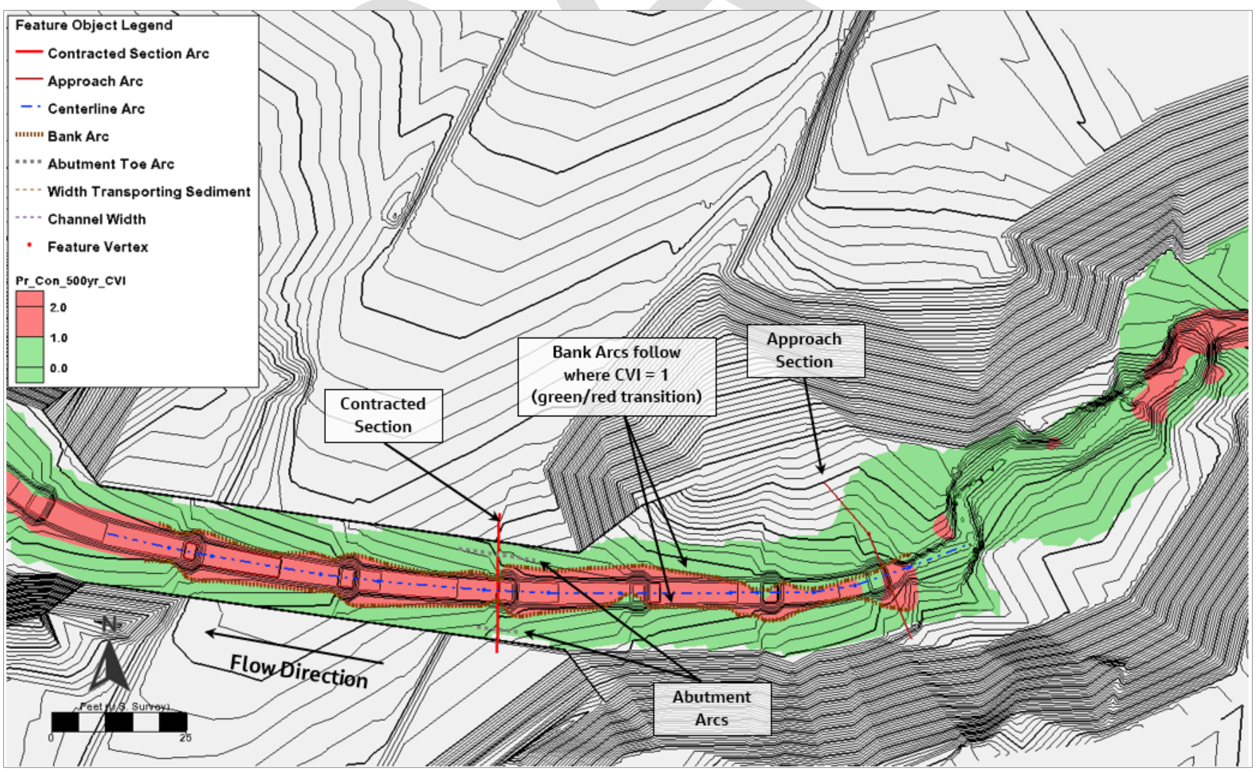


Figure 66: Location of bridge scour coverage arcs during scour design event

Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	1.31	ft	
D50	15.240000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	5.33	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	4.31	ft/s	
Contraction Scour Condition	Live Bed		
Live Bed & Clear Water Input Parameters			
Temperature of Water	50.00	ºF	
Slope of Energy Grade Line at Approach Section	0.033488	ft/ft	
Discharge in Contracted Section	44.05	cfs	
Discharge Upstream that is Transporting Sediment	58.17	cfs	
Width in Contracted Section	3.93	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	8.31	ft	
Depth Prior to Scour in Contracted Section	2.17	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	19.050000	mm	
Average Depth in Contracted Section after Scour	2.18	ft	
Scour Depth	0.00	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	1.19	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	1.67	ft	
Scour Depth	-0.50	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	0.6433	lb/ft^2	
Shear Required for Movement of D50 Particle	0.2001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.50	ft	Negative values imply 'zero' ...

Figure 67: Results for main channel live bed contraction scour for the scour design event

7.4 Local Scour

The following sections describe the scour methodology and results for the different local scour components included within this crossing.

7.4.1 Pier Scour

The crossing will not have piers and therefore pier scour was not calculated.

7.4.2 *Abutment Scour*

Abutment scour was estimated using the National Cooperative Highway Research Program (NCHRP) 24-20 (Ettema et al. 2010) approach for the scour design flood and scour check flood. Based on the geometry of the crossing and potential for lateral migration, Scour Condition A (main channel hydraulics) was considered applicable for all flows examined. Calculations assumed vertical abutment walls with wing walls based on the road geometry and fill depth. The NCHRP equation applies an amplification factor to contraction scour to account for the effects of large-scale turbulence of scour along an abutment. NCHRP 24-20 calculates a maximum flow depth, including abutment scour at the abutment. The design team assumes abutment scour occurs at the location of the contracted section; however, if the channel migrates, it could occur at any location through the structure. To account for this, scour depth is referenced as a depth below the thalweg by adjusting the flow depth prior to scour to the thalweg depth. Abutment scour equations estimate a depth of scour of 0.7 feet at the scour design and check flood (both are the 2080, 100-year flood). The hydraulic toolbox results for abutment scour at the left abutment wall are shown on Figure 68.

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutment		
Unit Discharge, Upstream in Main Channel (q1)	7.00	cfs/ft	
Unit Discharge in Constricted Area (q2)	11.34	cfs/ft	
D50	15.240000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	1.31	ft	
Define Shear Stress of Floodplain			
Flow Depth prior to Scour	2.31	ft	Depth at Abutment Toe
Results			
q2 / q1	1.62		
Average Velocity Upstream	5.33	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	4.31	ft/s	
Scour Condition	Live Bed		
Scour Condition	a (Main Channel)		
Amplification Factor	1.49		
Flow Depth including Contraction Scour	1.99	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	2.97	ft	Including the long-term scour de...
Scour Hole Depth	0.66	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...
Scour Hole Bottom Width	0.00	ft	
Scour Hole Top Width	0.68	ft	

Figure 68: Hydraulic toolbox results for left bank abutment scour

7.4.3 Bend Scour

Bend scour was not quantified at this crossing given the lack of anticipated bends in the vicinity of the crossing.

7.5 Total Scour

Table 20 provides calculated depths of scour for the proposed UNT to Kinman Creek at SR 3 structure. HEC-18 (Arneson et al. 2012) guidance is to not combine local abutment scour with contraction scour, since it includes and amplifies contraction scour; therefore, the larger of the two values is recommended. Total scour is estimated to be 2.2 feet during the 2080, 100-year event. No structure type has been recommended by WSDOT HQ Hydraulics.

Table 20: Calculated scour analysis summary for SR 3 at UNT to Kinman Creek

Scour Condition	Contracted Section of SR 3 UNT to Kinman Creek[a]
	Design and Check Flood Event 2080, 100-year
Long-Term Degradation (feet)	1.5
Contraction Scour (feet)	0.0
Local Abutment Scour (feet)	0.7
Total Depth of Scour (feet)	**2.2**

a. Depth of scour is referenced to a depth below thalweg (pool elevation).

8 Scour Countermeasures

The need for scour countermeasures has not yet been determined. If scour countermeasures are needed, the structure free zone will be determined additional to the minimum hydraulic opening. The minimum hydraulic opening, as described in Section 4.2, is 18 feet. Figure 69 is a copy of Figure 7-8 from WSDOT's *Hydraulics Manual* (2022a), showing a conceptual layout for when scour countermeasures are needed, given the presence of abutment scour.

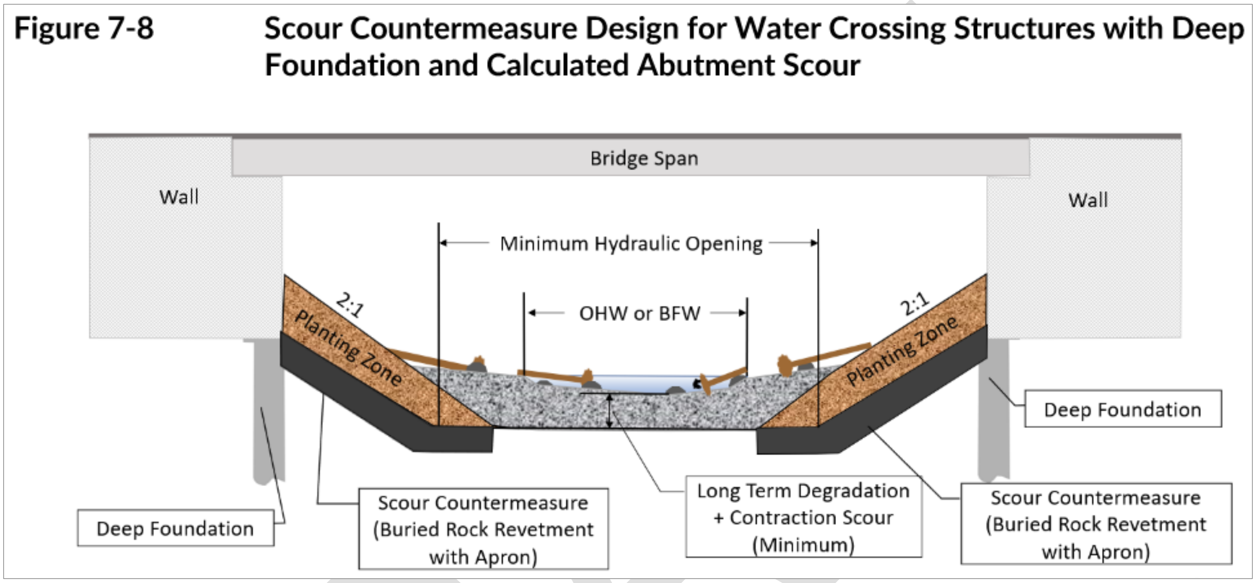


Figure 69: Conceptual diagram of scour countermeasures (WSDOT 2022a, p. 7-29).

9 Summary

Table 21 presents a summary of the results of this PHD report.

Table 21: Report summary

Stream crossing category	Element	Value	Report location
Habitat gain	Total length	5,676 LF	1.0 Introduction
Bankfull width	Reference reach found?	Yes	2.7.1 Reference Reach Selection
	Design BFW	6.0 ft	2.7.2 Channel Geometry
	Concurrence BFW	6.0 ft	2.7.2 Channel Geometry
Floodplain utilization ratio	Average FPW	20.2 ft	2.7.2.1 Floodplain Utilization Ratio
	Average FUR	US = 3.7 DS = 1.3	2.7.2.1 Floodplain Utilization Ratio
Channel morphology	Existing	Step-glide	2.7.2 Channel Geometry
	Proposed	Step-glide	4.3.2 Channel Complexity
Hydrology/design flows	100 yr flow	54 cfs	3 Hydrology and Peak Flow Estimates
	2080, 100 yr flow	84 cfs	3 Hydrology and Peak Flow Estimates
	2080, 100 yr used for design	Y	3 Hydrology and Peak Flow Estimates
	Dry channel in summer	No	2.4 Fish Presence in the Project Area
Channel geometry	Existing	See link	2.7.2 Channel Geometry
	Proposed	See link	4.1.1 Channel Planform and Shape
Channel slope/gradient	Existing culvert	2.5%	2.1 Site Description
	Reference reach	1.6%	2.7.1 Reference Reach Selection
	Proposed	1.8% at runs	4.1.3 Channel Gradient
Hydraulic width	Existing	3.0 ft	2.6.2 Existing Conditions
	Proposed	18.0 ft	4.2.2 Hydraulic Width
	Added for climate resilience	No	4.2.2 Hydraulic Width
Vertical clearance	Required freeboard	2.0 ft	4.2.3 Vertical Clearance
	Required freeboard applied to 100 yr or 2080, 100 yr	2080, 100 yr	4.2.3 Vertical Clearance
	Maintenance clearance	Recommended 6.0 ft	4.2.3 Vertical Clearance
	Low chord elevation	See link	4.2.3 Vertical Clearance
Crossing length	Existing	84.0 ft	2.6.2 Existing Conditions
	Proposed	90.0 ft	4.3.2.1 Design Concept
Structure type	Recommendation	No	4.2.6 Structure Type
	Type	N/A	4.2.6 Structure Type
Substrate	Existing	See link	2.7.3 Sediment
	Proposed	See link	4.3.1 Bed Material
	Coarser than existing?	Yes	4.3.1 Bed Material
Channel complexity	LWM for bank stability	No	4.3.2 Channel Complexity
	LWM for habitat	Yes	4.3.2 Channel Complexity
	LWM within structure	No	4.3.2 Channel Complexity
	Meander bars	0	4.3.2 Channel Complexity
	Boulder clusters	0	4.3.2 Channel Complexity
	Coarse bands	3	4.3.2 Channel Complexity
	Mobile wood	No	4.3.2 Channel Complexity

Stream crossing category	Element	Value	Report location
Floodplain continuity	FEMA mapped floodplain	No	2.1 Site Description
	Lateral migration	No	2.7.5 Channel Migration
	Floodplain changes?	Yes	6 Floodplain Evaluation
Scour	Analysis	See link	7 Scour Analysis
	Scour countermeasures	Determined at FHD	8 Scour Countermeasures
Channel degradation	Potential?	No	7.2 Long-term Degradation of the Channel Bed
	Allowed?	Yes	7.2 Long-term Degradation of the Channel Bed

References

Aquaveo. 2020. Surface-water Modeling System (SMS), Version 13.1.17. https://www.aquaveo.com/software/sms-surface-water-modeling-system-introduction.

Arcement, George J., and Verne R. Schneider. 1989. “Guide for Selecting Manning’s Roughness Coefficients for Natural Channels and Flood Plains.” *Water Supply Paper 2339*. U.S. Geological Survey. Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration. https://doi.org/10.3133/wsp2339.

Arneson, L. A., L. W. Zevenbergen, P. F. Lagasse, P. E. Clopper. 2012. *Evaluating Scour at Bridges,* Fifth Edition. Publication No. FHWA-HIF-12-003. Hydraulic Engineering Circular No 18 (HEC-18). Federal Highway Administration. Washington, DC. https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif12003.pdf.

Barnard, R. J., J. Johnson, P. Brooks, K. M. Bates, B. Heiner, J. P. Klavas, D. C. Ponder, P. D. Smith, and P. D. Powers (Barnard et al.). 2013. *Water Crossing Design Guidelines*. Washington Department of Fish and Wildlife. Olympia, WA. https://wdfw.wa.gov/publications/01501.

Chow, V. T. 1959. *Open Channel Hydraulics.* McGraw-Hill book Company, NY.

Church, M., and A. Zimmermann. 2007. “Form and Stability of Step-Pool Channels: Research Progress.” *Water Resources Research*, V. 43, W03415. March. https://doi.org/10.1029/2006WR005037.

Cluer, Brian, and Colin R. Thorne. 2013. “A Stream Evolution Model Integrating Habitat and Ecosystem Benefits.” *River Research and Applications*. Vol. 30, No. 2, pp. 135-267. https://doi.org/10.1002/rra.2631.

Cramer, Michelle L. (managing editor). 2012. *Stream Habitat Restoration Guidelines*. Copublished by the Washington Departments of Fish and Wildlife, Natural Resources, Transportation and Ecology, Washington State Recreation and Conservation Office, Puget Sound Partnership, and the U.S. Fish and Wildlife Service. Olympia, Washington. April.

Ecology (Washington State Department of Ecology). n.d. Water Resource Inventory Areas (geodatabase). https://ecology.wa.gov/Research-Data/Data-resources/Geographic-Information-Systems-GIS/Data. Accessed December 2021.

Ecology. 2021. *Watershed Restoration and Enhancement Draft Plan*. WRIA 15, Kitsap Watershed. Final Draft. Revised March 1.

ESRI. n.d. Aerial Imagery Web Map Service. http://goto.arcgisonline.com/maps/World_Imagery. Accessed December 2021.

Ettema, Robert, Tatsuaki Nakato, and Marian Muste. 2010. *Estimation of Scour Depth at Bridge Abutments*, *NCHRP 24-20.* Draft Final. The University of Iowa. National Cooperative Highway Research Program. Transportation Research Board, Washington, DC. January.

Federal Highway Administration. 2021. HY-8 Culvert Hydraulic Analysis Program, Version 7.50. U.S. Department of Transportation. https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/. July 28.

FEMA (Federal Emergency Management Agency). 2017. Flood Insurance Study Number: 53035C0085F.

Fox, Martin, and Susan Bolton. 2007. "A Regional and Geomorphic Reference for Quantities and Volumes of Instream Wood in Unmanaged Forested Basins of Washington State." *North American Journal of Fisheries Management*, Vol. 27, No. 1, pp. 342-359. https://doi.org/10.1577/M05-024.1.

Haugerud, Ralph A. 2009. Preliminary Geomorphic Map of the Kitsap Peninsula, Washington: U.S. Geological Survey, Open-File Report 2009-1033, 2 sheets, scale 1:36,000. https://pubs.usgs.gov/of/2009/1033/.

Heilman, Julie, State Hydraulics Engineer, WSDOT. 2022. Email transmittal of WSDOT document "Meander Bars for Water Crossing Structures in Stream Simulation Design Considerations for Success" (undated). To Nicholas VanBuecken, Stream Restoration Discipline Lead, Jacobs Engineering Group Inc. et al. April 12.

Kitsap County. 2017. Kitsap County GIS. https://www.kitsapgov.com/dis/Pages/resources.aspx. Accessed December 2021.

Lagasse, P. F., L. W. Zevenbergen, W. J. Spitz, and L. A. Arneson. 2012. *Stream Stability at Highway Structures*. Hydraulic Engineering Circular No. 20 (HEC-20). Fourth Edition. Publication FHWA-HIF-12-004. Federal Highway Administration. Washington, DC. https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif12004.pdf.

Limerinos, J. T. 1970. "Determination of the Manning Coefficient from Measured Bed Roughness in Natural Channels, Studies of Flow in Alluvial Channels." U.S. Geological Survey Water-Supply Paper 1898-B. United Stated Government Printing Office, Washington, DC.

Mastin, M. C., C. P. Konrad, A. G. Veilleux, and A. E. Tecca (Mastin et al.). 2017. "Magnitude, Frequency, and Trends of Floods at Gaged and Ungaged Sites in Washington, Based on Data through Water Year 2014" (Ver 1.2, November 2017): *U.S. Geological Survey Scientific Investigations Report 2016–5118*. https://doi.org/10.3133/sir20165118.

MGS Software LLC. 2021. MGSFlood Version 4.54. http://www.mgsengr.com/index.html. Accessed December 2021.

MRLC (Multi-Resolution Land Characteristics Consortium). 2019a. National Land Cover Database 2019 Land Cover (CONUS). https://www.mrlc.gov/data?f%5B0%5D=category%3Aland%20cover&f%5B1%5D=region%3Aconus.

MRLC. 2019b. National Land Cover Database, 2019 Percent Developed Imperviousness (CONUS). https://www.mrlc.gov/data?f%5B0%5D=category%3Aurban%20imperviousness&f%5B1%5D=region%3Aconus.

National Marine Fisheries Service. n.d. Essential Fish Habitat Mapper. https://www.habitat.noaa.gov/apps/efhmapper/?page=page_4. Accessed March 5, 2022.

NRCS USDA (Natural Resources Conservation Service, U. S. Department of Agriculture). 2021. Web Soil Survey. "Kitsap County Area, Washington." https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

NWIFC (Northwest Indian Fisheries Commission). n.d. Statewide Washington Integrated Fish Distribution dataset. https://geo.nwifc.org/swifd/.

PRISM Climate Group, Oregon State University. 2021. "30-year Climate Normals." https://prism.oregonstate.edu/normals/. Accessed November 2021.

Richardson, E. V., D. B. Simons, and P. F. Lagasse. 2001. *River Engineering for Highway Encroachments, Highways in the River Environment*. Publication FHWA NHI 01-004. Hydraulic Design Series No. 6. Federal Highway Administration, Washington, DC. December.

Rosgen, D. 1994. "A Classification of Natural Rivers." *Catena 22*, pp. 166–199.

U.S. Department of the Interior, Bureau of Reclamation. 2020. Sedimentation and River Hydraulics – Two Dimension, Version 3.3.1. https://www.usbr.gov/tsc/techreferences/computer%20software/models/srh2d/index.html#:~:text=About%20SRH%2D2D,transport%20model%20for%20river%20systems.

USGS (U.S. Geological Survey). 2019. National Hydrography Plus H Dataset 1711 HUC 4. https://prd-tnm.s3.amazonaws.com/index.html?prefix=StagedProducts/Hydrography/NHDPlusHR/Beta/GDB/. Accessed May 2020.

USGS and Quantum Spatial. 2018. Western Washington 3DEP LiDAR. Digital Terrain Model. Available at Washington State Department of Natural Resources (WADNR) Division of Geology and Earth Resources. https://lidarportal.dnr.wa.gov. Accessed December 2021.

Washington State Recreation and Conservation Office. n.d. Project database search by WRIA. https://secure.rco.wa.gov/prism/search/projectsearch.aspx. Accessed March 5, 2022.

WDFW (Washington Department of Fish and Wildlife). 2004. WDFW Fish Passage and Diversion Screening Inventory Database: 991242 Site Description Report. http://apps.wdfw.wa.gov/fishpassagephotos/Reports/991242_Report.pdf. Accessed December 2021.

WDFW. 2019. *Fish Passage Inventory, Assessment, and Prioritization Manual*. https://wdfw.wa.gov/sites/default/files/publications/02061/Fish%20Passage%20Inventory%2C%20Assessment%2C%20and%20Prioritization%20Manual.pdf.

WDFW. n.d.-a. Future Projections for Climate-Adapted Culvert Design. https://culverts.wdfw-fish.us/report.html. Accessed December 2022.

WDFW. n.d.-b. Fish Passage and Diversion Screening Inventory: FP_Sites. https://geodataservices.wdfw.wa.gov/hp/fishpassage/index.html. Accessed November 2021.

WDFW. n.d.-c Hydraulic Project Approval database - Section/Township/Range. https://www.govonlinesaas.com/WA/WDFW/Public/Client/WA_WDFW/Public/Pages/SubReviewList.aspx. Accessed March 5, 2022.

WSDOT (Washington State Department of Transportation). 2021a. Survey data, collected September 2021, along UNT to Kinman Creek, Poulsbo, WA. For Jacobs, Bellevue, Washington.

WSDOT. 2021b. Geotechnical Scoping Memorandum, Unnamed to Kinman Creek (991242) - SR3 MP 57.23. November 1.

WSDOT. 2022a. *Hydraulics Manual*. Olympia, WA. Publication Number M 23-03.07. March 1.

WSDOT. 2022b. Boring Log A-564P-22, Advanced Geotechnical Scoping for Fish Passage: SR 003/Unnamed to Kinman Creek (991242). May.

Appendices

Appendix A: FEMA Floodplain Map

Appendix B: Hydraulic Field Report Form

Appendix C: Streambed Material Sizing Calculations

Appendix D: Stream Plan Sheets, Profile, Details

Appendix E: Manning’s Calculations

Appendix F: Large Woody Material Calculations

Appendix G: Future Projections for Climate-Adapted Culvert Design

Appendix H: SRH-2D Model Results

Appendix I: SRH-2D Model Stability and Continuity

Appendix J: Reach Assessment

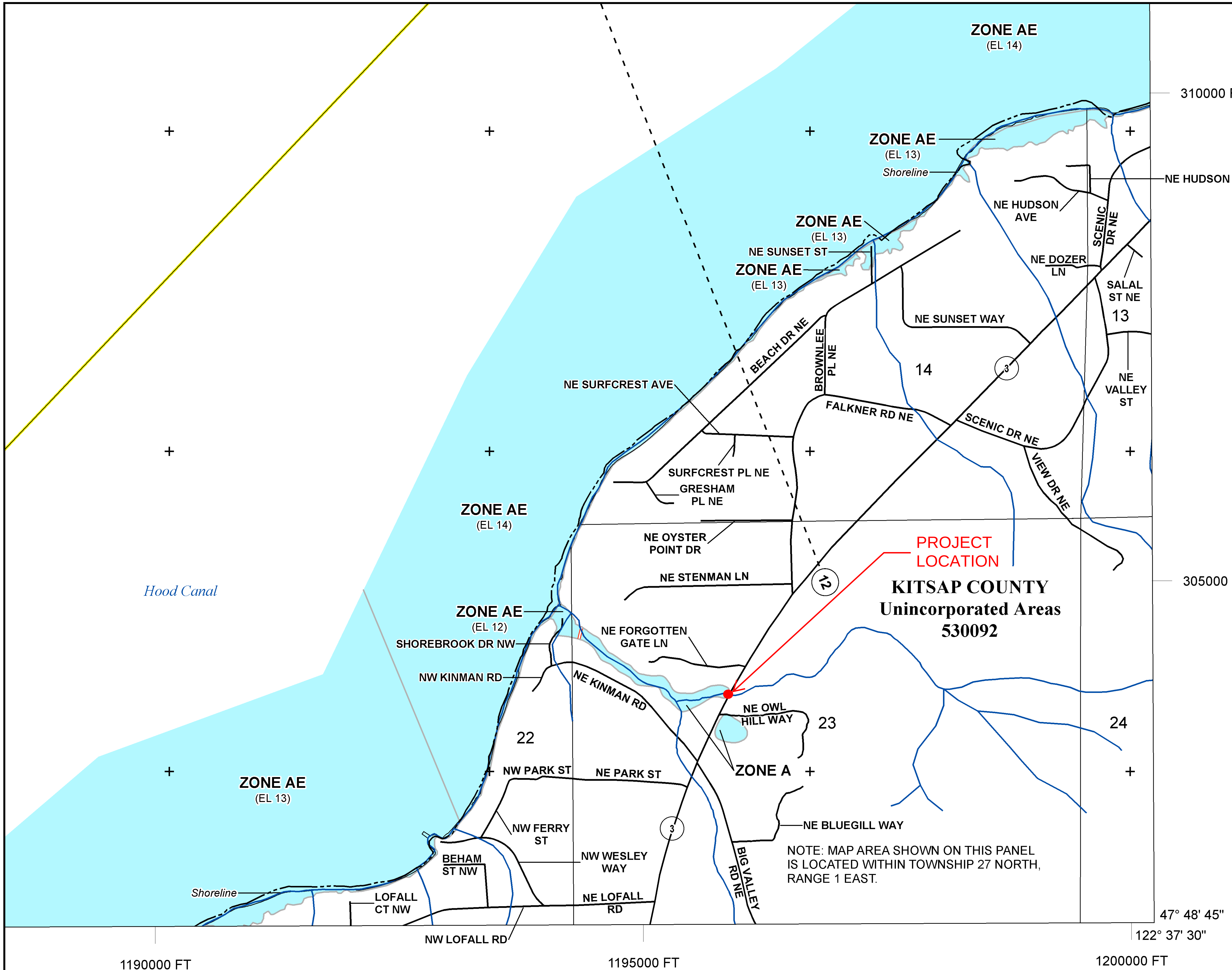
Appendix K: Scour Calculations

Appendix L: Floodplain Analysis (FHD ONLY)

Appendix M: Scour Countermeasure Calculations (FHD ONLY)

Appendix N: Hydrology

Appendix A: FEMA Floodplain Map



Map Projection:
NAD 1983 UTM Zone 10N;
Western Hemisphere; Vertical Datum: NAVD 88

1 inch = 1,000 feet

0 1,000 2,000

FEMA

National Flood Insurance Program

NATIONAL FLOOD INSURANCE PROGRAM
FLOOD INSURANCE RATE MAP

KITSAP COUNTY, WASHINGTON
AND INCORPORATED AREAS

PANEL 85 OF 525

FEMA

Panel Contains:

COMMUNITY	NUMBER	PANEL	SUFFIX
KITSAP COUNTY	530092	0085	F

VERSION NUMBER
2.2.2.1

MAP NUMBER
53035C0085F

MAP REVISED
FEBRUARY 3, 2017

This is an official FIRMette showing a portion of the above-referenced flood map created from the MSC FIRMette Web tool. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For additional information about how to make sure the map is current, please see the Flood Hazard Mapping Updates Overview Fact Sheet available on the FEMA Flood Map Service Center home page at https://msc.fema.gov.

National Flood Hazard Layer FIRMette

FEMA

122°38'52"W 47°49'21"N

122°38'15"W 47°48'56"N

Feet

0 250 500 1,000 1,500 2,000

1:6,000

Basemap: USGS National Map: Orthoimagery: Data refreshed October, 2020

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS		Without Base Flood Elevation (BFE) *Zone A, V, A99*
		With BFE or Depth *Zone AE, AO, AH, VE, AR*
		Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD		0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
		Future Conditions 1% Annual Chance Flood Hazard *Zone X*
		Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
		Area with Flood Risk due to Levee *Zone D*
OTHER AREAS	NO SCREEN	Area of Minimal Flood Hazard *Zone X*
		Effective LOMRs
		Area of Undetermined Flood Hazard *Zone D*
GENERAL STRUCTURES		Channel, Culvert, or Storm Sewer
		Levee, Dike, or Floodwall
OTHER FEATURES	B 20.2 17.5	Cross Sections with 1% Annual Chance Water Surface Elevation
	8	Coastal Transect
	513	Base Flood Elevation Line (BFE)
		Limit of Study
		Jurisdiction Boundary
		Coastal Transect Baseline
		Profile Baseline
		Hydrographic Feature
MAP PANELS		Digital Data Available
		No Digital Data Available
		Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 2/9/2022 at 6:51 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Appendix B: Hydraulic Field Report Form

Hydraulics Field Report		Project Number:
WSDOT Hydraulics Section	Project Name: PHD Unnamed to Kinman Creek	Date: 12/1/2021
	Project Office: Jacobs Engineering Group, Inc. Bellevue, WA	Time of Arrival: 11:30 am
	Stream Name: Unnamed tributary to Kinman Creek	Time of Departure: 1:00 PM
WDFW ID Number: 991242	Tributary to: Kinman Creek	Weather: Overcast and low 60's
State Route/MP: SR 3 / MP 57.23	Township/Range/Section/ ¼ Section: T 27 N, R 01 E, Section 23, NW ¼	Prepared By: MI
County: Kitsap	Purpose of Site Visit: Field Visit 2 and 3	WRIA: 15

Meeting Location:

Attendance List:

Name	Organization	Role
Nich VanBuecken	Y-12554 Olympic Region GEC	Stream Restoration Engineer
Karen Williams	Y-12554 Olympic Region GEC	Geomorphologist
Sage Jensen	Y-12554 Olympic Region GEC	Fisheries Biologist
Morgan Ruark	Y-12554 Olympic Region GEC	Hydraulics Engineer
Mark Indrebo	Y-12554 Olympic Region GEC	Geomorphologist
Channing Syms	Y-12554 Olympic Region GEC	Stream Restoration Engineer

Bankfull Width:

Describe measurements, locations, known history, summarize on site discussion.

Three bankfull width measurements were made downstream of the crossing, ranging from 6.0 to 6.9 feet. Three measurements were made upstream of the crossing. BFW measurements of 6 and 4 ft, respectively, were made upstream. All measurement locations are shown on the attached site map. Based on these data, a design BFW of 5 feet is suggested.

Reference Reach:

Describe location, known history, summarize on site discussion, appropriateness, bankfull measurement.

The reference reach is located upstream of the crossing, beginning about 120 feet upstream of the culvert inlet and extending upstream approximately 100 feet. Banks are generally about a foot high, and vertical in some locations but stable with mature vegetation consisting of a cedar canopy with sword fern undergrowth (Photo 1, Photo 2). The channel has a well-developed pool/riffle/run sequences (~35% forced pools, 10% riffle, 55% glide/run). The channel appears to be relatively undisturbed in recent years, though stumps in the vicinity with buckboard notches indicate that the area was logged historically.

Data Collection:

Describe who was involved, extents collection occurred within.

The crossing was visited by Jacobs staff on December 1, 2021. Jacobs staff investigated approximately 200 feet upstream of the culvert inlet and 200 feet downstream of the culvert outlet. Staff measured several BFW measurements, pebble counts, and large woody material (LWM) in the system, as noted in this field report. Additional observations on riparian condition and suitable habitat for anadromous and resident salmonids and trout were also made.

Observations:

Describe site conditions, channel geomorphology, habitat type and location, flow splits, LWM location and quantity, etc.

The existing crossing consists of 24-inch round concrete culvert west-northwest under SR 3, perpendicular to and approximately 10 feet below the road surface. According to the WSDOT survey, the channel upstream, downstream, and through the culvert is approximately 2.5%. Downstream of the crossing, the channel is incised 4 to 5 feet, with sandy banks and bed overgrown with non-native, invasive vegetation, predominantly Himalayan blackberry. The incision lessens downstream, and an overstory of deciduous trees begins approximately 75 feet downstream of the culvert outlet, but the blackberry and sandy banks and bed persist through the area observed in the field. One piece of LWM was noted in the downstream segment, an approximately 12 inch diameter, partially-decayed alder trunk roughly 12 feet long.

Upstream of the crossing, the first approximately 60 feet of channel roughly parallels the road prism before turning east into a more forested area, where the reference reach begins. The channel near the crossing is incised 1 to 3 feet, but further upstream the channel exhibits engagement with the floodplain. Upstream, the channel exhibits riffle and glide/run bedforms, punctuated by steps and pools formed from roots or other woody material (Photo 3). Streambed material in the glide reaches is dominated by sand and silt (D50 < 0.04 inches), and riffles are dominated by small gravel (D50 of 0.2 inches). The incised nature of the channel limits some floodplain development and access, but floodplain interaction were observed where gravel and sand were deposited such as on the right bank in Photo 2. No flow splits or floodplain channels were noted. Aside from live cedar roots, LWM was rare in the upstream reach, but accumulations of smaller organic material formed steps (Photo 3). Further upstream, the channel shows less to indicator of incision. Channel types are dominated by wood-forced pools and glides/runs separated by short riffles. Floodplain deposition was periodically observed.

Pebble Counts:

Describe location of pebble counts if available.

The downstream bed was almost entirely sand, with no viable locations for pebble counts. The upstream segment had more gravel, and four pebble counts were taken – two in riffles and two in glides – at locations shown on the attached sketch.

Photos:

Photo 1 - Upstream channel in reference reach


Photo 2 - BFW Measurement location in upstream channel segment


Photo 3 - Upstream segment. Roots and other organic material form steps and pools with gravel tailouts

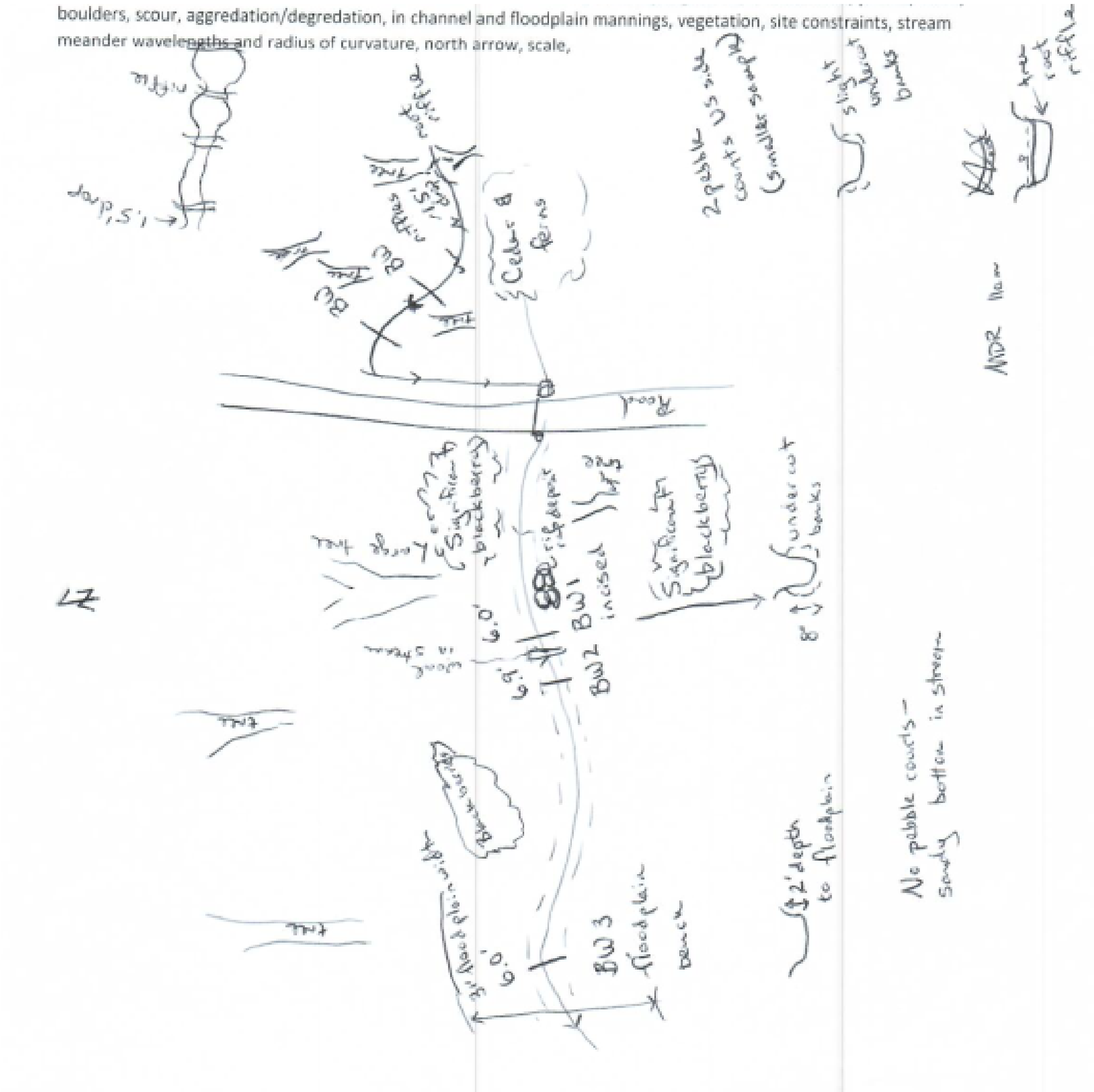


Figure 1 – Site Sketch

Samples:	
Work within the wetted perimeter may only occur during the time periods authorized in the APP ID 21036 entitled "Allowable Freshwater Work Times May 2018". Work outside of the wetted perimeter may occur year-round. APPS website: https://www.govonlinesaas.com/WA/WDFW/Public/Client/WA_WDFW/Shared/Pages/Main/Login.aspx	
Were any sample(s) collected from below the OHWM?	*No ☐ If no, then stop here.*
	Yes ☐ If yes, then fill out the proceeding section for each sample.

Sample #:	Work Start:	Work End:	Latitude:	Longitude:

Summary/description of location:

Summarize/describe the sample location.

Description of work below the OHWL:

Describe the work below the OHWL, including equipment used and quantity of sediment sampled.

Description of problems encountered:

Describe any problems encountered, such as provision violations, notification, corrective action, and impacts to fish life and water quality from problems that arose.

Concurrence Meeting

	Date: 1/21/2022	Time of Arrival: 8:00am
Prepared By: Jacobs Engineering Group Inc.	Weather: 40s and overcast	Time of Departure: 9:30am

Attendance List:

Name	Organization	Role
Nich VanBuecken	Y-12554 Olympic Region GEC - Jacobs	Stream Restoration Engineer
Reilly Holland	Y-12554 Olympic Region GEC - Jacobs	Stream Restoration Engineer
Kate Fauver	WSDOT	Senior Planner
Heather Pittman	WSDOT	OR Design Manager
Damon Romero	WSDOT	Fish Biologist
Dave Molenaar	WSDOT	Biology Program Manager
Alison O'Sullivan	Suquamish Tribe	Fish Biologist
Matt Curtis	WDFW	Scoping Section Manager
Nam Sim	WDFW	Fish Biologist
Dave Collins	WDFW	Fish Biologist
Shawn Stanley	WDFW	Habitat Engineer

Bankfull Width:

An upstream bankfull width (BFW) measurement was taken with all attendees and was determined to be 6 feet. Jacobs recommends rounding down the BFW and allowing the stream to naturally widen the channel to its desired width over time, particularly since the vertical banks are difficult to construct.

Several downstream BFW measurement were taken with all attendees and was determined to be an average of 7 feet. Five BFW measurements were resulting in values of 7, 8, 5, 9.5 and 6 feet. Attendees agreed with a design BFW of 6 feet based on the field measurements taken in the reference reach. However, channel materials will allow the channel to increase width over time.

Reference Reach:

All attendees confirmed the reference reach will be upstream of the culvert, approximately 120 feet from the inlet. The channel is engaged with the floodplain, evidenced by obvious deposition on the floodplain. The reference reach primarily consists of longer (5-10 ft) riffles, run, and glides at relatively low slope separated by wood debris-facilitated steps. Most of the grade change occurs at these steps. Banks are well-vegetated and cohesive. The channel within the crossing structure will emulate these characteristics. Additional information on the reference reach can be found in the site visit two field report above.

Reference reach step pool (local trees narrowed the BFW):

Downstream Pool: BFW = 4 feet, Pool Depth = 1.8 feet
Upstream Pool: BFW = 4.5 feet, Pool Depth = 1 foot
Change in Water Surface Elevation = 1.2 feet

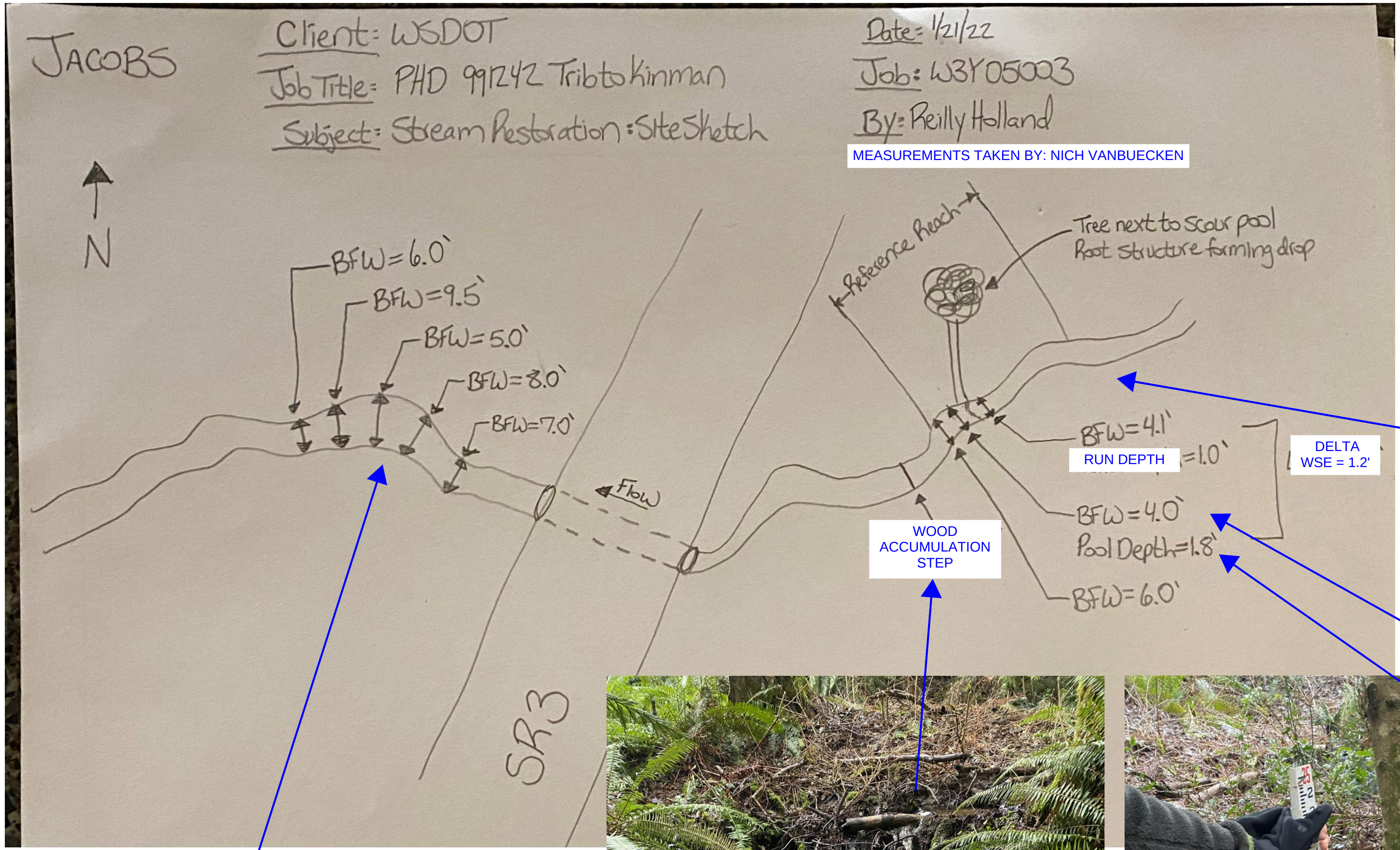
Observations:

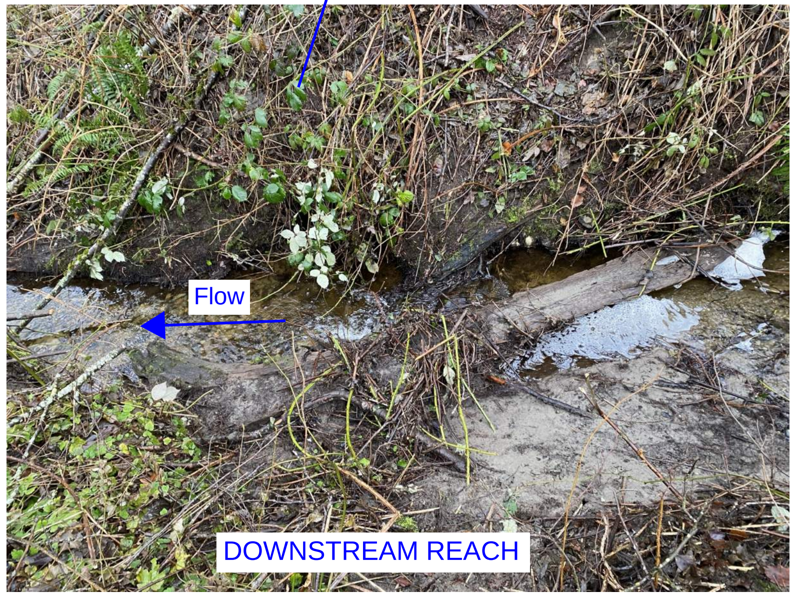
It was noted by WDFW that the watershed has a wetland complex and can likely attenuate some of the flows. Downstream it was noted that the channel is incised and the profile may need to be raised to offset the downcutting. Noting property lines for extent of project in degraded areas will need to be considered.

It should be noted that during the summer months there is heavy traffic in the area due to the Hood Canal Floating Bridge closing for water way traffic.

Photos:

Site sketches with associated photos for the January 21st field visit is attached.





No.	DATE	DSN	CHK	APP	REVISION

DESIGNED BY: M. KINSEY
DRAWN BY: M.KINSEY
CHECKED BY:
APPROVED BY:

Jacobs

REVIEWED BY:
SUBMITTED BY:
LINE IS 1" AT FULL SCALE

SCALE:
FILENAME:
CONTRACT No.: Y-12554
DATE: 11/29/2021

DESIGN PACKAGE:
PERMIT INFORMATION:

OLYMPIC REGION PHDS
Y-12554

991242 - UNT TO KINMAN CREEK
SV3 - SITE SKETCH

DRAWING No.: **PLAN 1**
FACILITY ID:
SHEET No.:
REV: 0

11/29/21 | 4:46 PM | KINSEYM2
P:\W3Y05000\600DISC\991241 SF JOHNSON CR\CAD\5085_SFJOHNSONCRKTOJOHNSONCRK.DWG

Fish Passage Project Site Visit - Determining Project Complexity

PROJECT NAME:	Unnamed to Kinman
WDFW SITE ID:	991242
STATE ROUTE/MILEPOST:	SR 3 MP 57.23
SITE VISIT DATE:	11/30/2021
ATTENDEES:	Nich VanBuecken, Karen Williams, Sage Jensen, Channing Syms, Mark Indrebo
ANTICIPATED LEVEL OF PROJECT COMPLEXITY - Low/Medium/High (*additional considerations or red flags may trigger the need for new discussions*):	Medium
IN WATER WORK WINDOW	??

The following elements of projects should be discussed before the production of a Preliminary Hydraulic Design by members of WSDOT and WDFW to identify the level of complexity for each site, and corresponding communication and review. While certain elements may be categorized as indicators of a low/medium/high complexity project, these are only suggestions, and newly acquired information may change the level of complexity during a project. The ultimate documentation category for a given site is up to both WSDOT and WDFW, considering both site characteristics and synergistic effects.

Discuss the following elements as they apply to the project. Rank each element as low, medium, or high in complexity. If there are items that need follow-up, mark those and provide a brief description in the column labeled, “Is follow up needed on this item?” The assigned level of complexity determines the appropriate agreed upon review from WDFW (see review parameters here (*final full doc goes here*)). Ultimately, WSDOT needs to acquire an HPA from WDFW for fish passage projects and the agreed upon communication and review of project elements will contribute to efficiencies in the permitting process.

Fish Passage Project Site Visit - Determining Project Complexity

Project Elements (anticipated)	Low Complexity	Medium Complexity	High Complexity	Is follow up needed on this item?
Stream grading	x			Constant grade
Risk of degradation/aggradation	x			Sediment input appears to be similar to output
Channel realignment	x			Valley location set
Expected stream movement	x			Mature trees and high potential for LWM
Gradient		x		Ranges from 4% to 5% through stream and proposed culvert
Potential for backwater impacts	x			
Meeting requirements for freeboard	x			12 feet of clearance possible
Stream size, and Bankfull Width	x			BFW 6-7 ft
Slope ratio	x			Similar slopes
Sediment supply	x			
Meeting stream simulation	x			
Channel confinement		x		Channel confined in ravine through project; unconfined FUR
Geotech or seismic considerations		x		Seismic should be assessed
Tidal influence	x			No
Alluvial fan	x			No
Fill depth above barrier	x			12ft
Presence of other nearby barriers	x			No
Presence of nearby infrastructure		x		Home on left bank downstream
Need for bank protection	x			Unlikely.
Floodplain utilization ratio	x			Appears confined.

Fish Passage Project Site Visit - Determining Project Complexity

Other:				

Appendix C: Streambed Material Sizing Calculations

Attachment 1. SBM Sizing for Proposed Typical Channel

Summary - Stream Simulation Bed Material Design

991242 UNT to Kinman Cr - Riffle

Project:	**UNT to Kinman Creek**
By:	**Brandon Werner, EIT**

Design Gradation:

Location:	PC #1, Glide			
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.84	0.02	0.00	0.00
in	10.10	0.20	0.04	0.03
mm	256.54	5.08	1.02	0.76

Design Gradation:

Location:	PC #2, Riffle			
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.42	0.18	0.05	0.02
in	5.00	2.10	0.60	0.20
mm	127.00	53.34	15.24	5.08

Design Gradation:

Location:	PC #3, Glide			
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.08	0.03	0.00	0.00
in	0.90	0.40	0.03	0.00
mm	22.86	10.16	0.76	0.03

Design Gradation:

Location:	PC #4, Riffle			
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.08	0.04	0.02	0.00
in	0.90	0.50	0.20	0.04
mm	22.86	12.70	5.08	1.02

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organizms at Road-Stream Crossings

Appendix E--Methods for Streambed Mobility/Stability Analysis

Limitations:

D_{84} must be between 0.40 in and 10 in

uniform bed material (Di < 20-30 times D50)

Slopes less than 5%

Sand/gravel streams with high relative submergence

Equation E.6 $\tau_{ci} = 102.6\, \tau_{D50}\, D_i^{\,0.3}\, D_{50}^{\,0.7}$

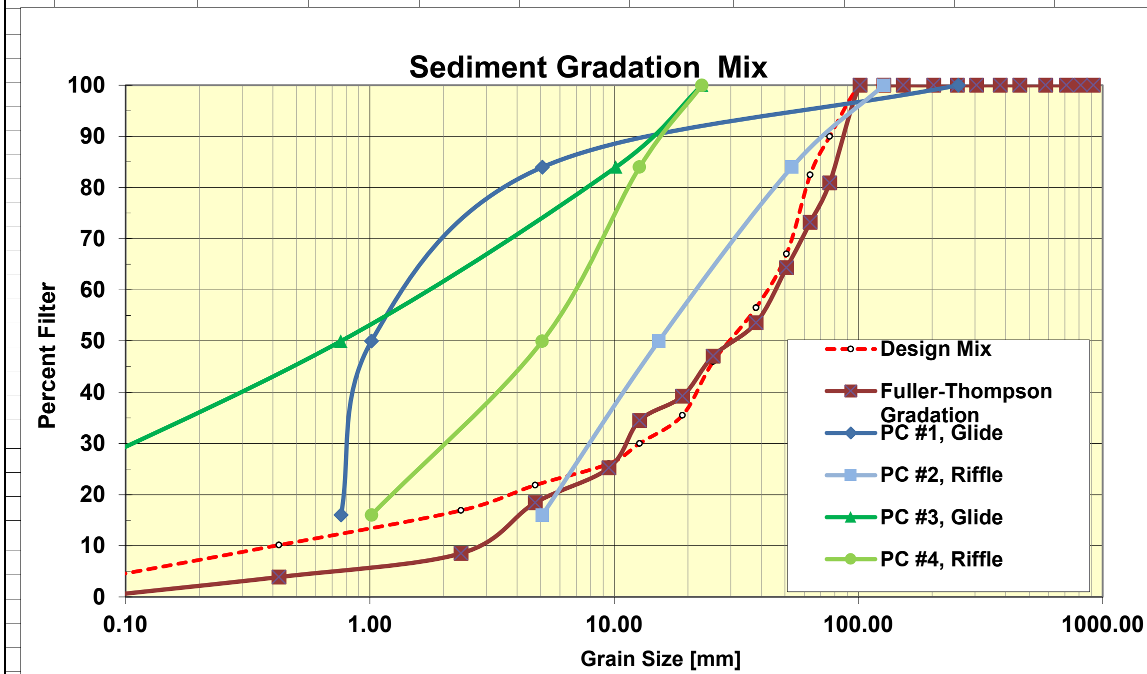
γ_s	165	specific weight of sediment particle (lb/ft^3)
γ	62.4	specific weight of water (1b/ft^3)
τ_{D50}	0.050	parameter for D50, use table E.1 of USFS

Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

	Rock Size [in]	[mm]	Streambed Sand	Streambed Sediment	Streambed Cobbles 4"	6"	8"	10"	12"	Streambed Boulders 12"-18"	18"-28"	28"-36"	D_{size}	τ_{ci}	Flow 2-YR (12 cfs)	100-YR (54 cfs)
														Average Modeled Shear Stress (	0.62	1.20
Boulders	36.0	914										100	100.0	1.42	No Motion	No Motion
	32.0	813										50	100.0	1.37	No Motion	No Motion
	28.0	711									100		100.0	1.31	No Motion	No Motion
	23.0	584									50		100.0	1.24	No Motion	No Motion
	18.0	457								100			100.0	1.15	No Motion	Motion
	15.0	381								50			100.0	1.09	No Motion	Motion
Cobbles	12.0	305							100				100.0	1.02	No Motion	Motion
	10.0	254						100	80				100.0	0.96	No Motion	Motion
	8.0	203					100	80	68				100.0	0.90	No Motion	Motion
	6.0	152				100	80	68	57				100.0	0.83	No Motion	Motion
	5.0	127				80	68	57	45				100.0	0.78	No Motion	Motion
	4.0	102			100	71	57	45	39				100.0	0.73	No Motion	Motion
Gravel	3.0	76.2			80	63	45	38	34				90.0	0.67	No Motion	Motion
	2.5	63.5		100	65	54	37	32	28				82.5	0.64	No Motion	Motion
	2.0	50.8		80	50	45	29	25	22				67.0	0.59	Motion	Motion
	1.5	38.1		73	35	32	21	18	16				56.5	0.55	Motion	Motion
	1.0	25.4		65	20	18	13	12	11				46.0	0.48	Motion	Motion
	0.75	19.1		58	5	5	5	5	5				35.5	0.44	Motion	Motion
	0.50	12.7	100	50									30.0	0.39	Motion	Motion
	0.38	9.5	90	43									26.0	0.36	Motion	Motion
	No. 4 =	4.75	79	35									21.9			
	No. 8 =	2.36	67	26									16.9	Max Tau =	0.64	
Sand	No. 40 =	0.425	37	16									10.1	Flow	Q2	Q100
Silt	No. 200 =	0.0750	7	7									3.5	D84 FOS	1.0	0.5
	% per category		10	40	50	0	0	0	0	0	0	0	*--> 100%*			
	% Cobble & Sediment		10.0	40.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*100.0%*			

%	mm	in	ft
10.1	0.4	0.0	
16	2.1	0.1	0.007
16.9	2.4	0.1	
46.00	25.4	1.0	
50	30.2	1.2	0.099
56.50	38.1	1.5	
82.50	63.5	2.5	
84	66.0	2.6	0.217
90.00	76.2	3.0	



Fuller-Thompson Gradation

Dmax =	**101.6**	4	
	D[mm]	D[in]	% passing
	914.400	36	100.00
	812.800	32	100.00
	711.200	28	100.00
	584.200	23	100.00
	457.200	18	100.00
	381.000	15	100.00
	304.800	12	100.00
	254.000	10	100.00
	203.200	8	100.00
	152.400	6	100.00
	127.000	5	100.00
	101.600	4	100.00
	76.200	3	80.94
	63.500	2.5	73.20
	50.800	2	64.32
	38.100	1.5	53.59
	25.400	1.00	47.08
	19.050	0.75	39.23
	12.700	0.50	34.47
	9.525	0.375	25.20
	4.750	0.187	18.40
	2.360	0.093	8.50
	0.425	0.017	3.90
	0.075	0.0030	0.00

Attachment 2. SBM Sizing for Proposed Forcing Elements and Coarse Bands Heads

Summary - Stream Simulation Bed Material Design

991242 UNT to Kinman Cr - Forcing Element Head

Project:	Trib to Kinman Creek
By:	Brandon Werner, EIT

Design Gradation:

Location:	PC #1, Glide			
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.84	0.02	0.00	0.00
in	10.10	0.20	0.04	0.03
mm	256.54	5.08	1.02	0.76

Design Gradation:

Location:	PC #2, Riffle			
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.42	0.18	0.05	0.02
in	5.00	2.10	0.60	0.20
mm	127.00	53.34	15.24	5.08

Design Gradation:

Location:	PC #3, Glide			
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.08	0.03	0.00	0.00
in	0.90	0.40	0.03	0.00
mm	22.86	10.16	0.76	0.03

Design Gradation:

Location:	PC #4, Riffle			
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.08	0.04	0.02	0.00
in	0.90	0.50	0.20	0.04
mm	22.86	12.70	5.08	1.02

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organizms at Road-Stream Crossings

Appendix E--Methods for Streambed Mobility/Stability Analysis

Limitations:

D_{84} must be between 0.40 in and 10 in

uniform bed material (Di < 20-30 times D50)

Slopes less than 5%

Sand/gravel streams with high relative submergence

Equation E.6 $\tau_{ci} = 102.6\ \tau_{D50}\ D_i^{0.3}\ D_{50}^{0.7}$

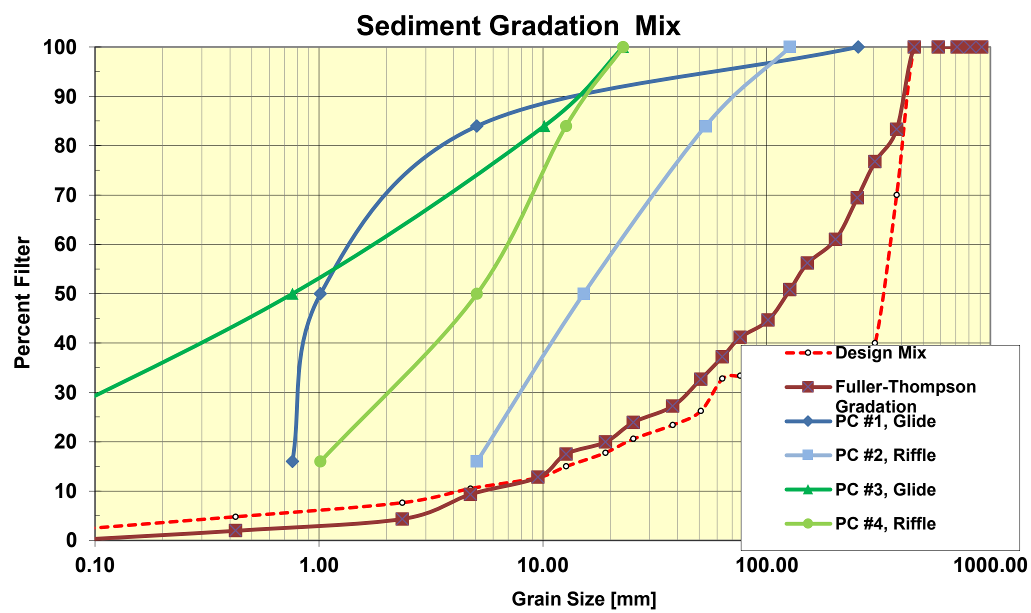
γ_s	165	specific weight of sediment particle (lb/ft^3)
γ	62.4	specific weight of water (1b/ft^3)
τ_{D50}	0.054	parameter for D50, use table E.1 of USFS

Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

	Rock Size [in]	[mm]	Streambed Sand	Streambed Sediment	Streambed Cobbles 4"	6"	8"	10"	12"	Streambed Boulders 12"-18"	18"-28"	28"-36"	D_{size}	τ_{ci}	Flow: 2-YR (12 cfs)	100-YR (54 cfs)
														Average Modeled Shear Stress (	2.38	4.06
Boulders	36.0	914										100	100.0	8.15	No Motion	No Motion
	32.0	813										50	100.0	7.87	No Motion	No Motion
	28.0	711									100		100.0	7.56	No Motion	No Motion
	23.0	584									50		100.0	7.13	No Motion	No Motion
	18.0	457								100			100.0	6.62	No Motion	No Motion
	15.0	381								50			70.0	6.27	No Motion	No Motion
Cobbles	12.0	305							100				40.0	5.86	No Motion	No Motion
	10.0	254						100	80				38.0	5.55	No Motion	No Motion
	8.0	203					100	80	68				36.8	5.19	No Motion	No Motion
	6.0	152				100	80	68	57				35.7	4.76	No Motion	No Motion
	5.0	127				80	68	57	45				34.5	4.51	No Motion	No Motion
	4.0	102			100	71	57	45	39				33.9	4.22	No Motion	No Motion
Gravel	3.0	76.2			80	63	45	38	34				33.4	3.87	No Motion	Motion
	2.5	63.5		100	65	54	37	32	28				32.8	3.66	No Motion	Motion
	2.0	50.8		80	50	45	29	25	22				26.2	3.43	No Motion	Motion
	1.5	38.1		73	35	32	21	18	16				23.4	3.14	No Motion	Motion
	1.0	25.4		65	20	18	13	12	11				20.6	2.78	No Motion	Motion
	0.75	19.1		58	5	5	5	5	5				17.8	2.55	No Motion	Motion
	0.50	12.7	100	50									15.0	2.26	Motion	Motion
	0.38	9.5	90	43									12.8	2.07	Motion	Motion
	No. 4 =	4.75	79	35									10.5			
	No. 8 =	2.36	67	26									7.7	Max Tau =	6.44	
Sand	No. 40 =	0.425	37	16									4.8	Flow	Q2	Q100
Silt	No. 200 =	0.0750	7	7									2.1	D84 FOS	2.7	1.6
	% per category		0	30	0	0	0	0	10	60	0	0	--> 100%			
	% Cobble & Sediment		0.0	75.0	0.0	0.0	0.0	0.0	25.0	150.0	0.0	0.0	40.0%			

%	mm	in	ft
15.0	12.7	0.5	
16	15.0	0.6	0.049
17.8	19.1	0.8	
40.00	304.8	12.0	
50	330.5	13.0	1.084
70.00	381.0	15.0	
70.00	381.0	15.0	
84	416.6	16.4	1.367
100.00	457.2	18.0	



Fuller-Thompson Gradation			
Dmax =	457.2	18	
	D[mm]	D[in]	% passing
	914.400	36	100.00
	812.800	32	100.00
	711.200	28	100.00
	584.200	23	100.00
	457.200	18	100.00
	381.000	15	83.32
	304.800	12	76.76
	254.000	10	69.43
	203.200	8	61.00
	152.400	6	56.19
	127.000	5	50.82
	101.600	4	44.65
	76.200	3	41.13
	63.500	2.5	37.20
	50.800	2	32.69
	38.100	1.5	27.23
	25.400	1.00	23.93
	19.050	0.75	19.94
	12.700	0.50	17.52
	9.525	0.375	12.81
	4.750	0.187	9.35
	2.360	0.093	4.32
	0.425	0.017	1.98
	0.075	0.0030	0.00

Attachment 3. SBM Sizing for Proposed Forcing Elements and Coarse Bands Tails

Summary - Stream Simulation Bed Material Design

991242 UNT to Kinman Cr - Forcing Element Tail

Project:	Trib to Kinman Creek
By:	Brandon Werner, EIT

Design Gradation:

Location: PC #1, Glide

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.84	0.02	0.00	0.00
in	10.10	0.20	0.04	0.03
mm	256.54	5.08	1.02	0.76

Design Gradation:

Location: PC #2, Riffle

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.42	0.18	0.05	0.02
in	5.00	2.10	0.60	0.20
mm	127.00	53.34	15.24	5.08

Design Gradation:

Location: PC #3, Glide

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.08	0.03	0.00	0.00
in	0.90	0.40	0.03	0.00
mm	22.86	10.16	0.76	0.03

Design Gradation:

Location: PC #4, Riffle

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.08	0.04	0.02	0.00
in	0.90	0.50	0.20	0.04
mm	22.86	12.70	5.08	1.02

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organizms at Road-Stream Crossings

Appendix E--Methods for Streambed Mobility/Stability Analysis

Limitations:

D_{84} must be between 0.40 in and 10 in

uniform bed material (Di < 20-30 times D50)

Slopes less than 5%

Sand/gravel streams with high relative submergence

Equation E.6 $\tau_{ci} = 102.6\,\tau_{D50}\,D_i^{\,0.3}\,D_{50}^{\,0.7}$

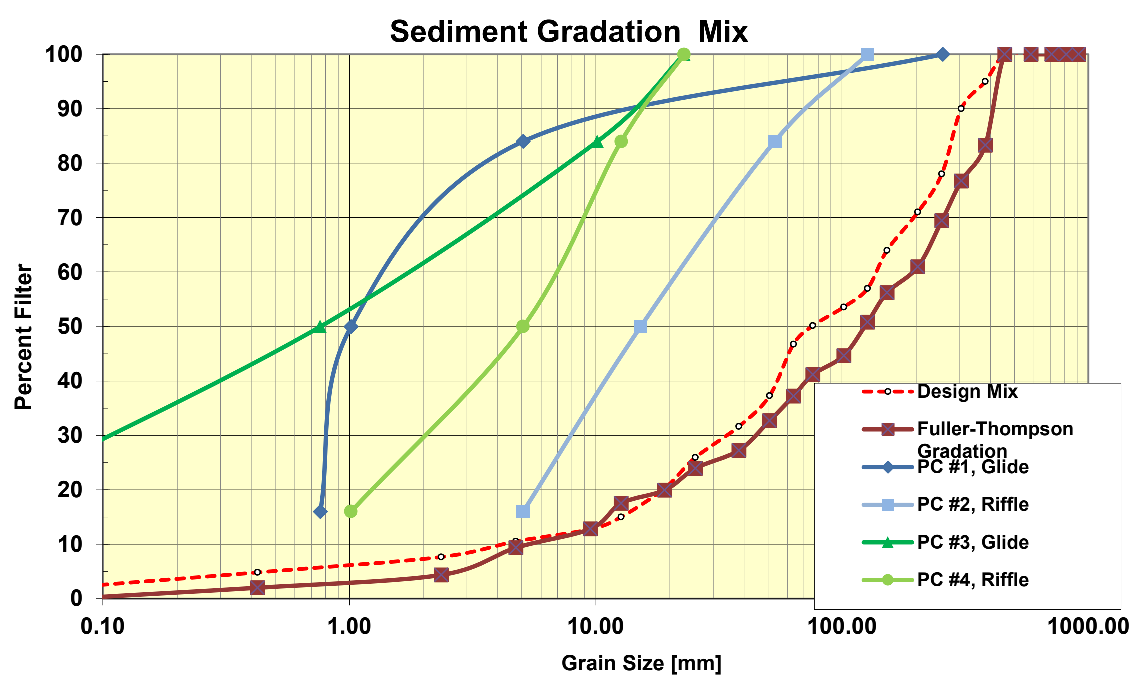
γ_s	165	specific weight of sediment particle (lb/ft^3)
γ	62.4	specific weight of water (1b/ft^3)
τ_{D50}	0.054	parameter for D50, use table E.1 of USFS

Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

	Rock Size [in]	[mm]	Streambed Sand	Streambed Sediment	Streambed Cobbles 4"	6"	8"	10"	12"	Streambed Boulders 12"-18"	18"-28"	28"-36"	D_{size}	τ_{ci}	Flow 2-YR (12 cfs)	100-YR (54 cfs)
														Average Modeled Shear Stress (	2.38	4.06
Boulders	36.0	914										100	100.0	2.91	No Motion	Motion
	32.0	813										50	100.0	2.81	No Motion	Motion
	28.0	711									100		100.0	2.70	No Motion	Motion
	23.0	584									50		100.0	2.55	No Motion	Motion
	18.0	457								100			100.0	2.37	Motion	Motion
	15.0	381								50			95.0	2.24	Motion	Motion
Cobbles	12.0	305							100				90.0	2.10	Motion	Motion
	10.0	254						100	80				78.0	1.98	Motion	Motion
	8.0	203					100	80	68				71.0	1.86	Motion	Motion
	6.0	152				100	80	68	57				64.0	1.70	Motion	Motion
	5.0	127				80	68	57	45				57.0	1.61	Motion	Motion
	4.0	102			100	71	57	45	39				53.6	1.51	Motion	Motion
Gravel	3.0	76.2			80	63	45	38	34				50.1	1.38	Motion	Motion
	2.5	63.5		100	65	54	37	32	28				46.7	1.31	Motion	Motion
	2.0	50.8		80	50	45	29	25	22				37.3	1.22	Motion	Motion
	1.5	38.1		73	35	32	21	18	16				31.6	1.12	Motion	Motion
	1.0	25.4		65	20	18	13	12	11				25.9	0.99	Motion	Motion
	0.75	19.1		58	5	5	5	5	5				20.3	0.91	Motion	Motion
	0.50	12.7	100	50									15.0	0.81	Motion	Motion
	0.38	9.5	90	43									12.8	0.74	Motion	Motion
	No. 4 =	4.75	79	35									10.5			
	No. 8 =	2.36	67	26									7.7	Max Tau =	2.04	
Sand	No. 40 =	0.425	37	16									4.8	Flow	Q2	Q100
Silt	No. 200 =	0.0750	7	7									2.1	D84 FOS	0.9	0.5
	% per category		0	30	0	0	0	0	60	10	0	0	--> 100%			
	% Cobble & Sediment		0.0	33.3	0.0	0.0	0.0	0.0	66.7	11.1	0.0	0.0	90.0%			

%	mm	in	ft
15.0	12.7	0.5	
16	13.9	0.5	0.046
20.3	19.1	0.8	
46.71	63.5	2.5	
50	76.0	3.0	0.249
50.14	76.2	3.0	
78.00	254.0	10.0	
84	279.4	11.0	0.917
90.00	304.8	12.0	

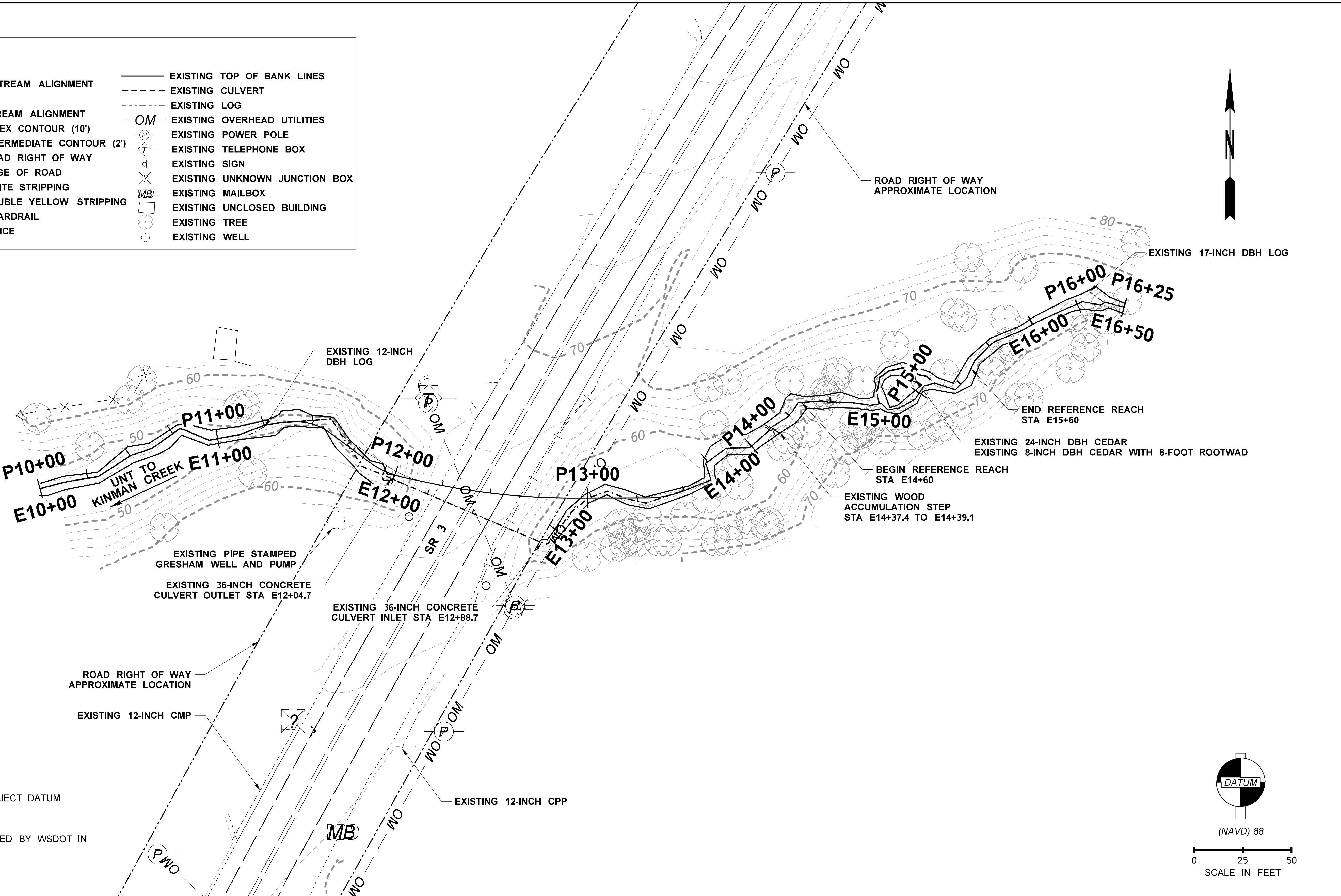


Fuller-Thompson Gradation			
Dmax =	457.2	18	
	D[mm]	D[in]	% passing
	914.400	36	100.00
	812.800	32	100.00
	711.200	28	100.00
	584.200	23	100.00
	457.200	18	100.00
	381.000	15	83.32
	304.800	12	76.76
	254.000	10	69.43
	203.200	8	61.00
	152.400	6	56.19
	127.000	5	50.82
	101.600	4	44.65
	76.200	3	41.13
	63.500	2.5	37.20
	50.800	2	32.69
	38.100	1.5	27.23
	25.400	1.00	23.93
	19.050	0.75	19.94
	12.700	0.50	17.52
	9.525	0.375	12.81
	4.750	0.187	9.35
	2.360	0.093	4.32
	0.425	0.017	1.98
	0.075	0.0030	0.00

Appendix D: Stream Plan Sheets, Profile, Details

LEGEND

P5+00 / E5+00 — PROPOSED STREAM ALIGNMENT	EXISTING TOP OF BANK LINES
EXISTING STREAM ALIGNMENT	EXISTING CULVERT
EXISTING INDEX CONTOUR (10')	EXISTING LOG
EXISTING INTERMEDIATE CONTOUR (2')	OM — EXISTING OVERHEAD UTILITIES
EXISTING ROAD RIGHT OF WAY	P — EXISTING POWER POLE
EXISTING EDGE OF ROAD	T — EXISTING TELEPHONE BOX
EXISTING WHITE STRIPPING	EXISTING SIGN
EXISTING DOUBLE YELLOW STRIPPING	? — EXISTING UNKNOWN JUNCTION BOX
EXISTING GUARDRAIL	MB — EXISTING MAILBOX
EXISTING FENCE	EXISTING UNCLOSED BUILDING
	EXISTING TREE
	EXISTING WELL



NOTES

1. HORIZONTAL DATUM: PROJECT DATUM
2. VERTICAL DATUM: NAVD88
3. FIELD SURVEY PERFORMED BY WSDOT IN SEPTEMBER 2021

FILE NAME	c:\pwworking\jacobs_b&i\pw_wsdot\d0462822\991242_Existing_Plan_View.dgn
TIME	3:13:55 PM
DATE	4/20/2022
PLOTTED BY	HollanRA
DESIGNED BY	R. HOLLAND
ENTERED BY	R. HOLLAND
CHECKED BY	K. WILLIAMS
PROJ. ENGR.	J. HEILMAN
REGIONAL ADM.	-

REVISION	DATE	BY

REGION NO. | STATE: WASH | FED.AID PROJ.NO. | JOB NUMBER | CONTRACT NO. | LOCATION NO.

PRELIMINARY
NOT FOR CONSTRUCTION

P.E. STAMP BOX DATE | P.E. STAMP BOX DATE

Washington State Department of Transportation

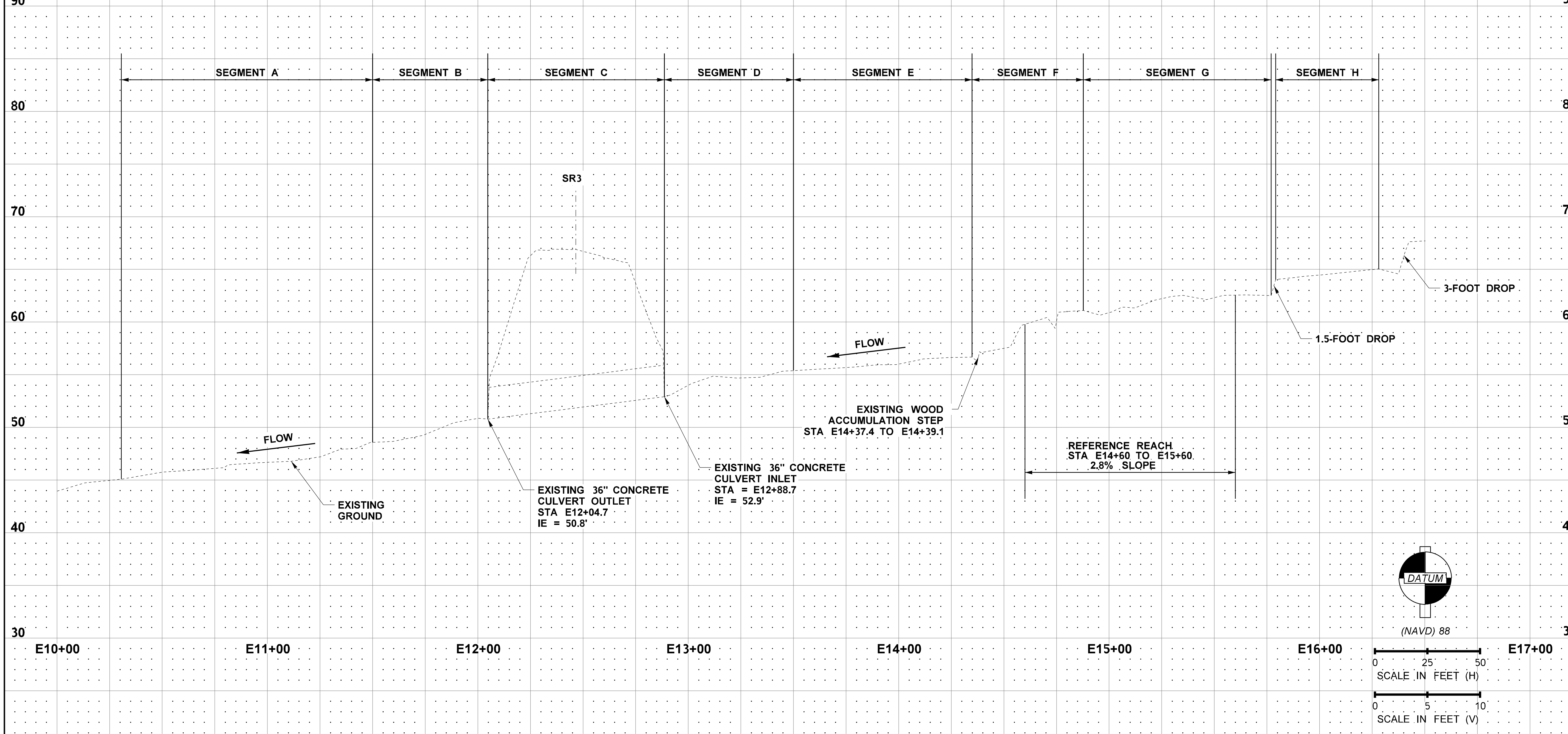
SR 3 MILE POST 57.23
991242 UNT TO KINMAN CREEK
FISH BARRIER REMOVAL

EXISTING STREAM PLAN

PLAN REF NO CE1

SHEET 1 OF 6 SHEETS

SR3 MP57.23 UNNAMED TO KINMAN CREEK				
SEGMENT	ELEVATION CHANGE (FT)	SEGMENT LENGTH (FT)	GRADIENT	MAX POOL DEPTH (FT)
A	3.5	119.4	2.9%	0.0
B	2.2	54.7	4.0%	0.0
C (CULVERT)	2.1	84.0	2.5%	0.0
D	2.5	61.3	4.0%	0.2
E	1.3	84.9	1.5%	0.2
F	4.4	52.9	8.4%	0.8
G	1.4	89.2	1.6%	0.6
H	1.0	49.0	2.1%	0.0



FILE NAME	c:\pwworking\jacobs_b&i\pw_wsdot\d0462822\991242_Existing_Profile_View.dgn			
TIME	3:12:37 PM			
DATE	4/20/2022			
PLOTTED BY	HollanRA			
DESIGNED BY	R. HOLLAND			
ENTERED BY	R. HOLLAND			
CHECKED BY	K. WILLIAMS			
PROJ. ENGR.	J. HEILMAN			
REGIONAL ADM.	-	REVISION	DATE	BY

REGION NO. | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER

CONTRACT NO. | LOCATION NO.

PRELIMINARY

NOT FOR CONSTRUCTION

DATE P.E. STAMP BOX

DATE P.E. STAMP BOX

Washington State Department of Transportation

SR 3 MILE POST 57.23
991242 UNT TO KINMAN CREEK
FISH BARRIER REMOVAL

EXISTING STREAM PROFILE

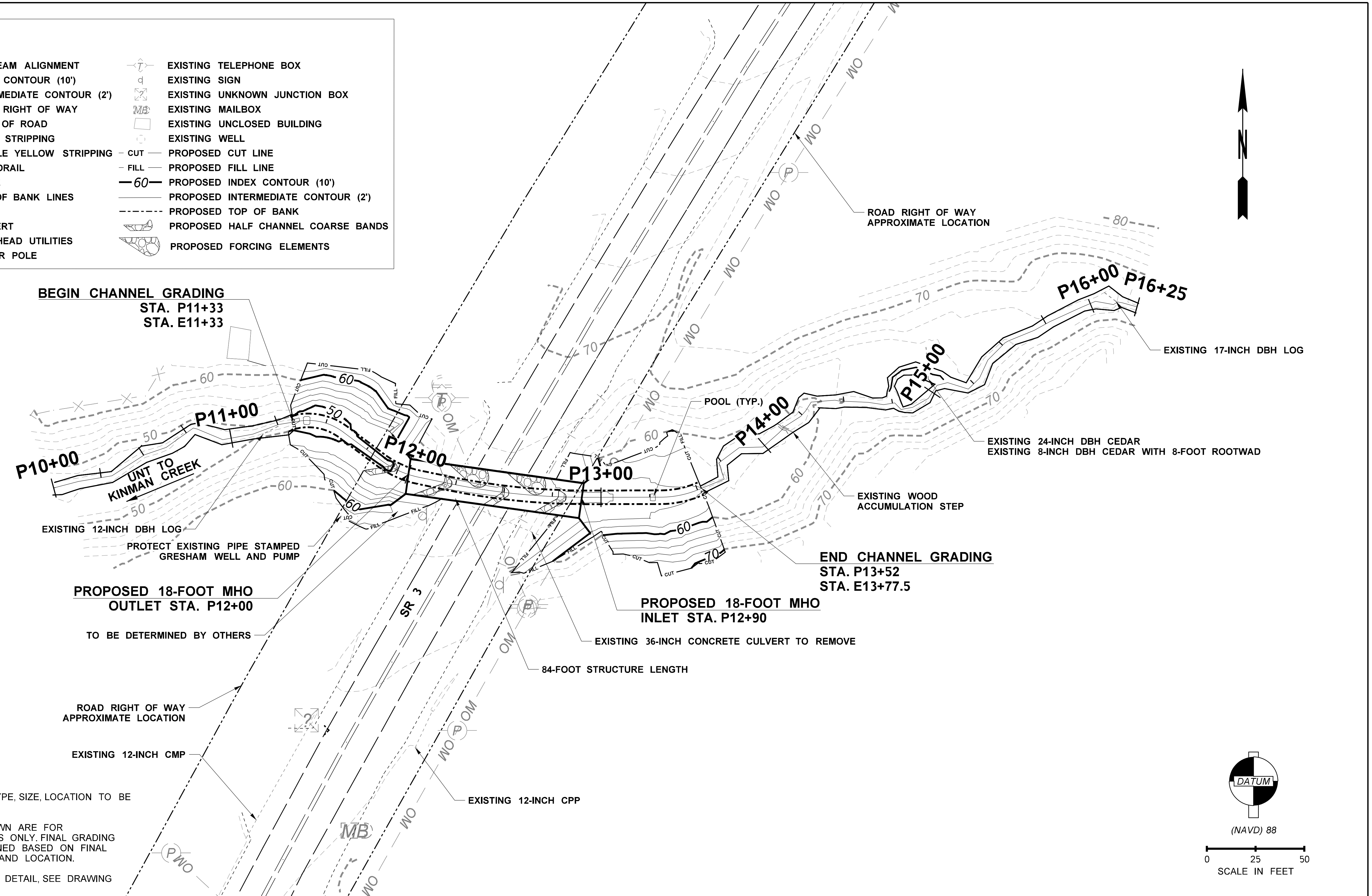
PLAN REF NO CP1

SHEET 2 OF 6 SHEETS

LEGEND

P5+00

Symbol	Description	Symbol	Description
	PROPOSED STREAM ALIGNMENT		EXISTING TELEPHONE BOX
60	EXISTING INDEX CONTOUR (10')		EXISTING SIGN
	EXISTING INTERMEDIATE CONTOUR (2')		EXISTING UNKNOWN JUNCTION BOX
	EXISTING ROAD RIGHT OF WAY	MB	EXISTING MAILBOX
	EXISTING EDGE OF ROAD		EXISTING UNCLOSED BUILDING
	EXISTING WHITE STRIPPING		EXISTING WELL
	EXISTING DOUBLE YELLOW STRIPPING	CUT	PROPOSED CUT LINE
	EXISTING GUARDRAIL	FILL	PROPOSED FILL LINE
	EXISTING FENCE	60	PROPOSED INDEX CONTOUR (10')
	EXISTING TOP OF BANK LINES		PROPOSED INTERMEDIATE CONTOUR (2')
	EXISTING LOG		PROPOSED TOP OF BANK
	EXISTING CULVERT		PROPOSED HALF CHANNEL COARSE BANDS
OM	EXISTING OVERHEAD UTILITIES		PROPOSED FORCING ELEMENTS
P	EXISTING POWER POLE		



NOTES

1. EXACT STRUCTURE TYPE, SIZE, LOCATION TO BE DETERMINED.

2. GRADING LIMITS SHOWN ARE FOR ILLUSTRATION PURPOSES ONLY. FINAL GRADING LIMITS TO BE DETERMINED BASED ON FINAL STRUCTURE TYPE, SIZE AND LOCATION.

3. FOR FURTHER POOLS DETAIL, SEE DRAWING CP2

FILE NAME	c:\pwworking\jacobs_b&i\pw_wsdot\d0462822\991242_Proposed_Plan_View.dgn
TIME	8:57:09 AM
DATE	2/13/2023
PLOTTED BY	HollanRA
DESIGNED BY	R. HOLLAND
ENTERED BY	R. HOLLAND
CHECKED BY	K. WILLIAMS
PROJ. ENGR.	J. HEILMAN
REGIONAL ADM.	-

REVISION | DATE | BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER XL5467		
CONTRACT NO. C9242		LOCATION NO.

PRELIMINARY
NOT FOR CONSTRUCTION

P.E. STAMP BOX DATE | P.E. STAMP BOX DATE

Washington State Department of Transportation

SR 3 MILE POST 57.23
991242 UNT TO KINMAN CREEK
FISH BARRIER REMOVAL

PROPOSED STREAM PLAN

PLAN REF NO CR1

SHEET 3 OF 6 SHEETS

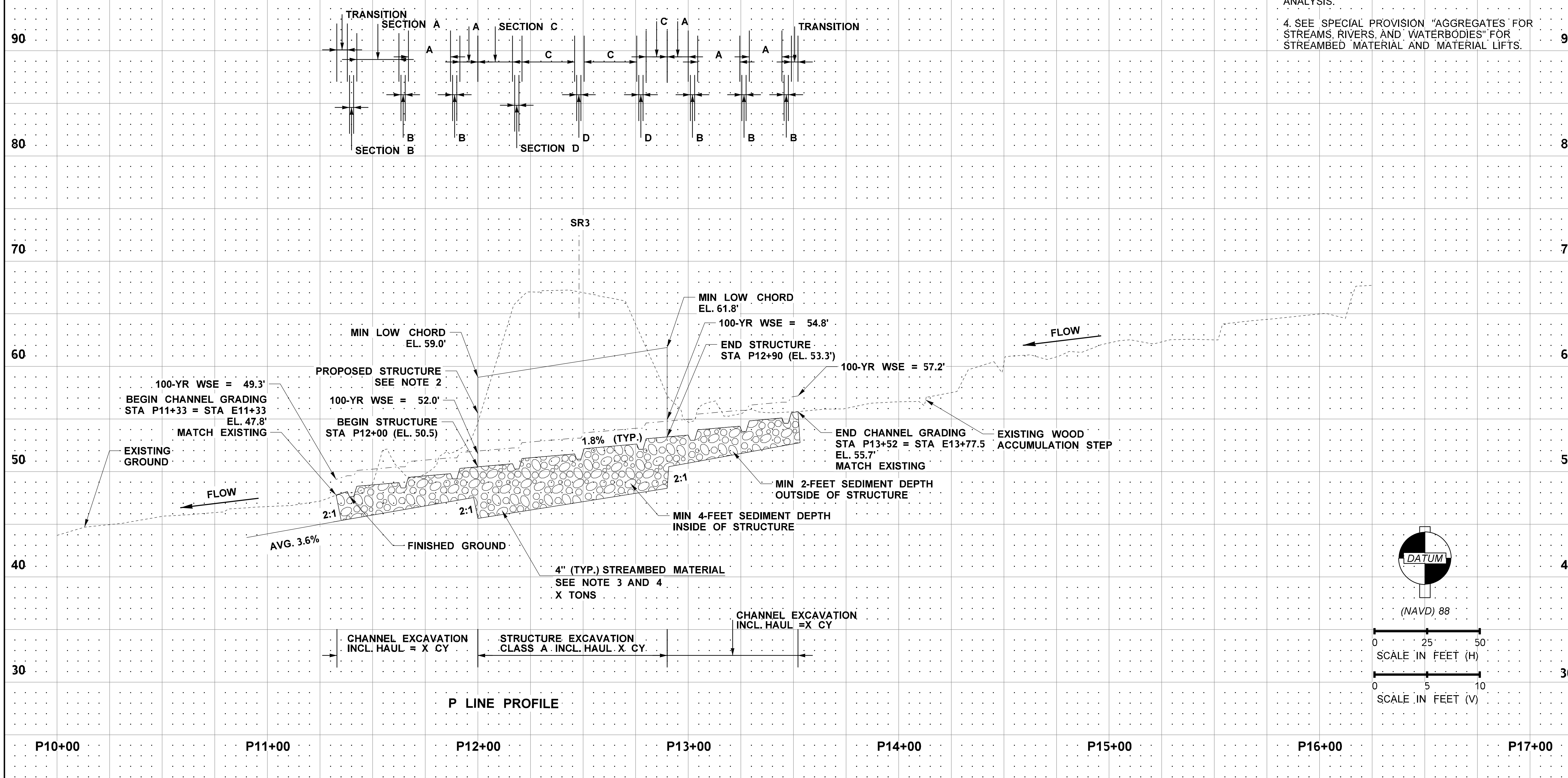
NOTES

1. GRADING LIMITS SHOWN ARE FOR ILLUSTRATION PURPOSES ONLY. FINAL GRADING LIMITS TO BE DETERMINED BASED ON FINAL STRUCTURE TYPE, SIZE AND LOCATION.

2. EXACT STRUCTURE TYPE, SIZE, LOCATION, AND WALLS TO BE DETERMINED.

3. MATERIAL DEPTH IS APPROXIMATE, FINAL DEPTH TO BE DETERMINED FOLLOWING SCOUR ANALYSIS.

4. SEE SPECIAL PROVISION "AGGREGATES FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIAL AND MATERIAL LIFTS.



P LINE PROFILE

FILE NAME	c:\pwworking\jacobs_b&i\pw_wsdot\d0462822\991242_Proposed_Profile View.dgn
TIME	4:35:58 PM
DATE	4/19/2022
PLOTTED BY	HollanRA
DESIGNED BY	R. HOLLAND
ENTERED BY	R. HOLLAND
CHECKED BY	K. WILLIAMS
PROJ. ENGR.	J. HEILMAN
REGIONAL ADM.	-

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER XL5467

CONTRACT NO. C9242

LOCATION NO.

PRELIMINARY

NOT FOR CONSTRUCTION

P.E. STAMP BOX DATE P.E. STAMP BOX DATE

Washington State Department of Transportation

SR 3 MILE POST 57.23
991242 UNT TO KINMAN CREEK
FISH BARRIER REMOVAL

PROPOSED STREAM PROFILE

PLAN REF NO CP2

SHEET 4 OF 6 SHEETS

NOTES:

1. SLOPES SHOWN OUTSIDE OF THE MINIMUM CHANNEL SECTION ARE FOR ILLUSTRATIVE PURPOSES ONLY TO DEPICT ESTIMATED AREA OF POTENTIAL IMPACT. FINAL AREAS OF IMPACT TO BE DETERMINED PENDING GEOTECHNICAL AND STRUCTURAL INVESTIGATION, STRUCTURE TYPE, AND STRUCTURE LOCATION.

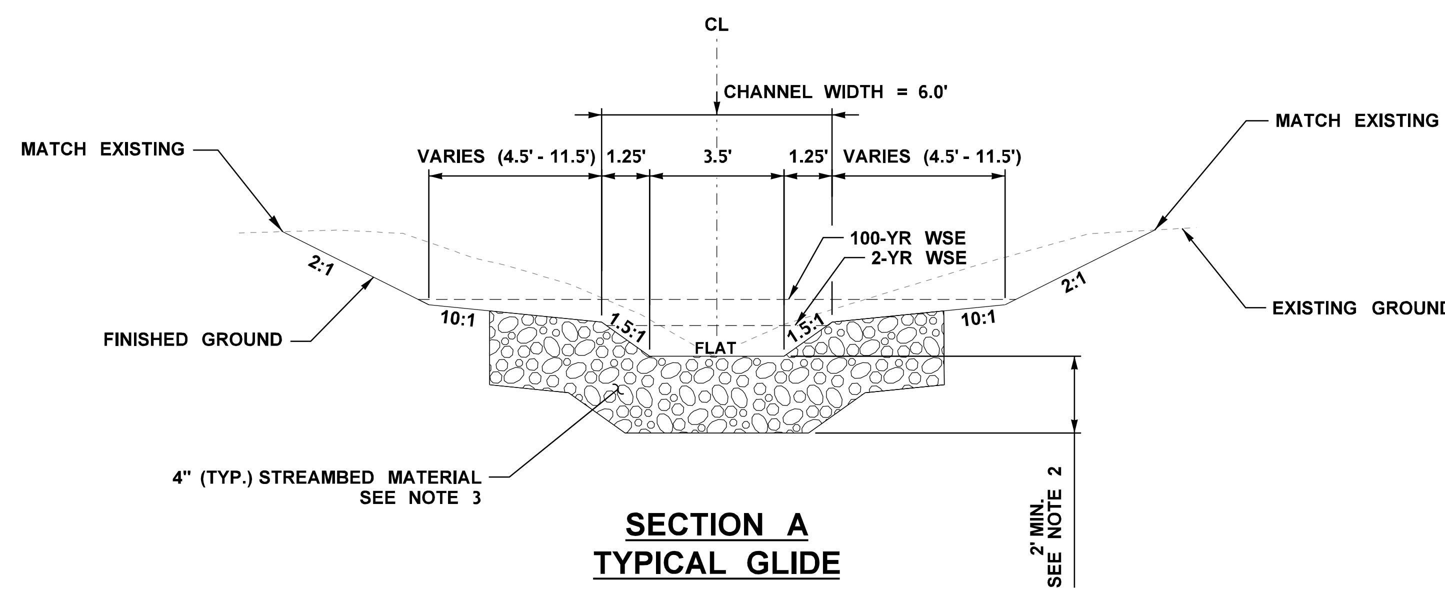
2. MATERIAL DEPTH IS APPROXIMATE. FINAL DEPTH TO BE DETERMINED FOLLOWING SCOUR ANALYSIS.

3. SEE SPECIAL PROVISION "AGGREGATES FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIAL AND MATERIAL LIFTS.

4. FROM 11+33 TO 11+38, EVENLY TAPER SECTION A TO MATCH EXISTING CHANNEL.

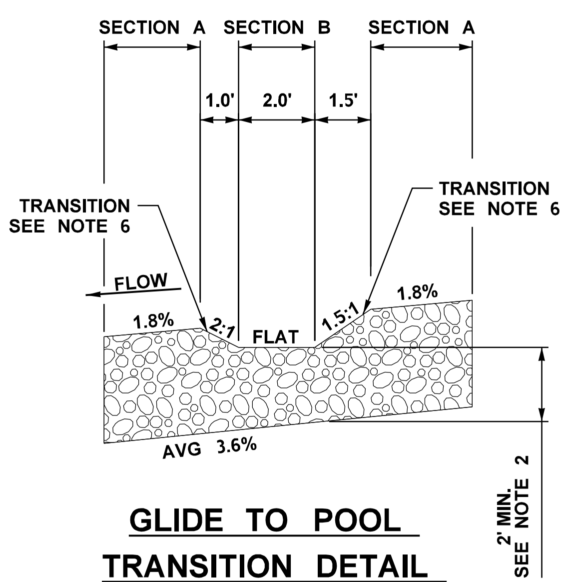
5. FROM 13+47 TO 13+52, EVENLY TAPER SECTION A TO MATCH EXISTING CHANNEL.

6. EVENLY TAPER SECTION A TO SECTION B USING A 1.5:1 SLOPE. EVENLY TAPER SECTION B TO SECTION A USING A 2:1 SLOPE.

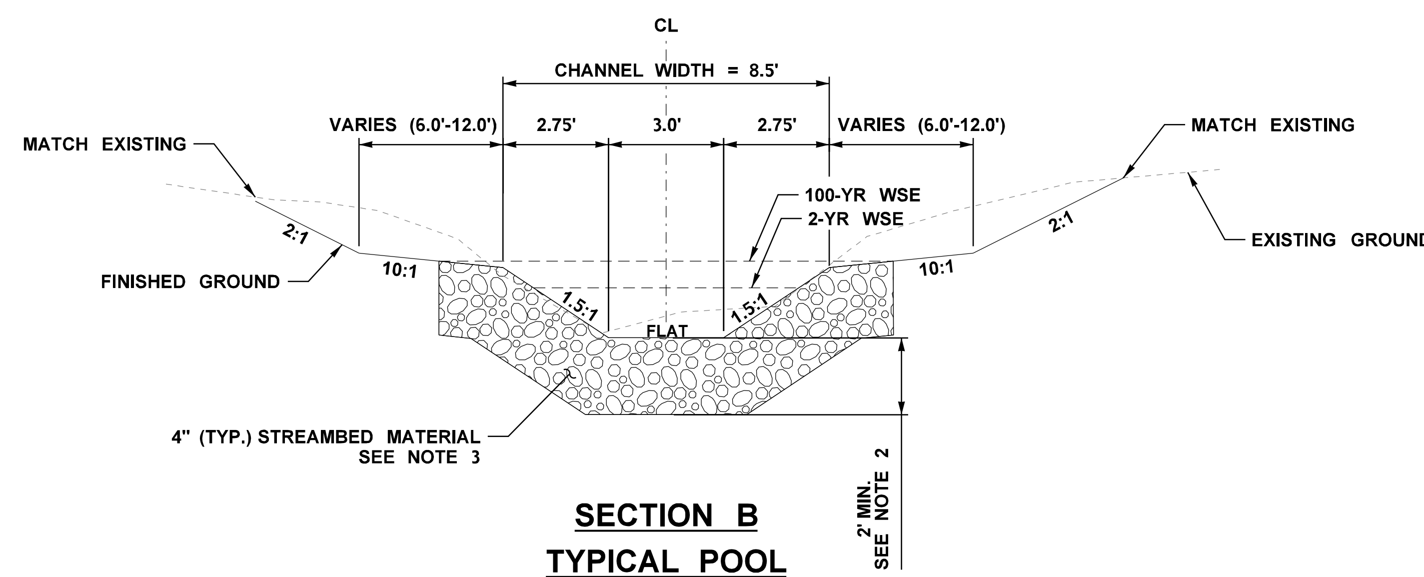


SECTION A
TYPICAL GLIDE

STA P11+32.0 TO STA P11+38.0
STA P11+42.5 TO STA P11+62.5
STA P11+67.0 TO STA P11+87.0
STA P11+91.5 TO STA P12+00.0
STA P12+90.0 TO STA P13+00.0
STA P13+04.5 TO STA P13+24.5
STA P13+29.0 TO STA P13+44.5
STA P13+49.0 TO STA P13+52.0



GLIDE TO POOL TRANSITION DETAIL BETWEEN SECTION A AND SECTION B



SECTION B
TYPICAL POOL

STA P11+39.0 TO STA P11+41.0
STA P11+63.5 TO STA P11+65.5
STA P11+88.0 TO STA P11+90.0
STA P13+01.0 TO STA P13+03.0
STA P12+25.5 TO STA P13+27.5
STA P13+45.5 TO STA P13+47.5

DATUM
(NAVD) 88

0 2.5 5
SCALE IN FEET (H)

0 2.5 5
SCALE IN FEET (V)

FILE NAME	c:\pwworking\jacobs_b&i\pw_wsdot\d0462822\991242_Proposed_CrossSection.dgn
TIME	2:00:11 PM
DATE	5/20/2022
PLOTTED BY	HollanRA
DESIGNED BY	R. HOLLAND
ENTERED BY	R. HOLLAND
CHECKED BY	K. WILLIAMS
PROJ. ENGR.	J. HEILMAN
REGIONAL ADM.	-

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER XL5467

CONTRACT NO. C9242 | LOCATION NO.

PRELIMINARY
NOT FOR CONSTRUCTION

P.E. STAMP BOX DATE
P.E. STAMP BOX DATE

Washington State Department of Transportation

SR 3 MILE POST 57.23
991242 UNT TO KINMAN CREEK
FISH BARRIER REMOVAL

PROPOSED STREAM CROSS SECTION

PLAN REF NO CD1

SHEET 5 OF 6 SHEETS

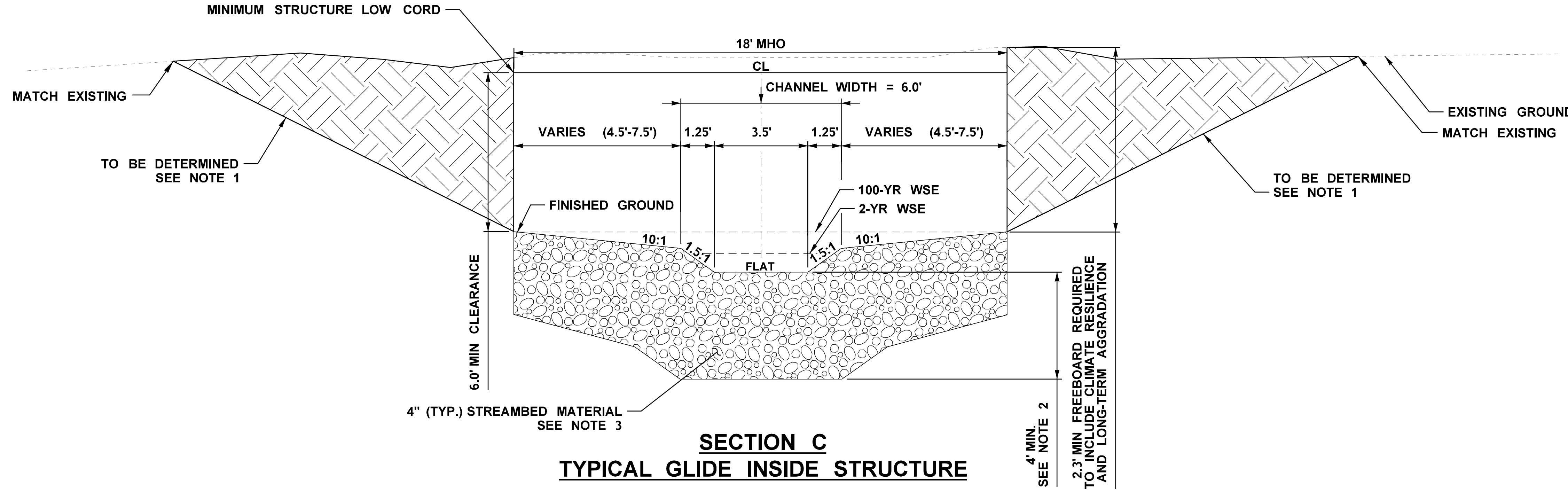
NOTES:

1. SLOPES SHOWN OUTSIDE OF THE MINIMUM CHANNEL SECTION ARE FOR ILLUSTRATIVE PURPOSES ONLY TO DEPICT ESTIMATED AREA OF POTENTIAL IMPACT. FINAL AREAS OF IMPACT TO BE DETERMINED PENDING GEOTECHNICAL AND STRUCTURAL INVESTIGATION, STRUCTURE TYPE, AND STRUCTURE LOCATION.

2. MATERIAL DEPTH IS APPROXIMATE. FINAL DEPTH TO BE DETERMINED FOLLOWING SCOUR ANALYSIS.

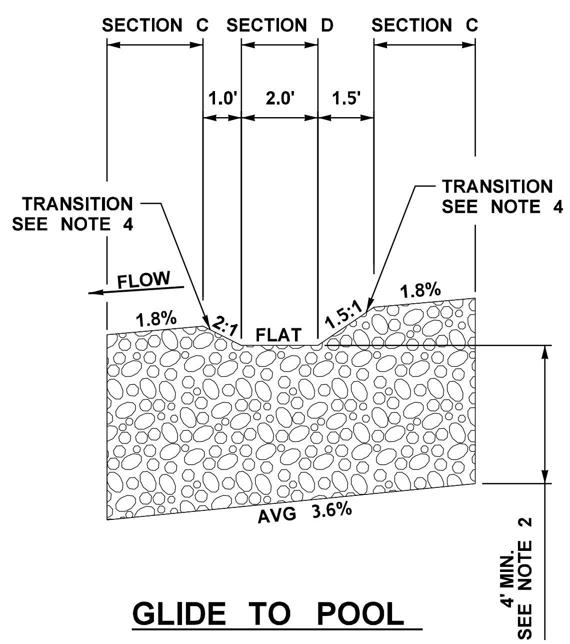
3. SEE SPECIAL PROVISION "AGGREGATES FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIAL AND MATERIAL LIFTS.

4. EVENLY TAPER SECTION C TO SECTION D USING A 1.5:1 SLOPE. EVENLY TAPER SECTION D TO SECTION C USING A 2:1 SLOPE.

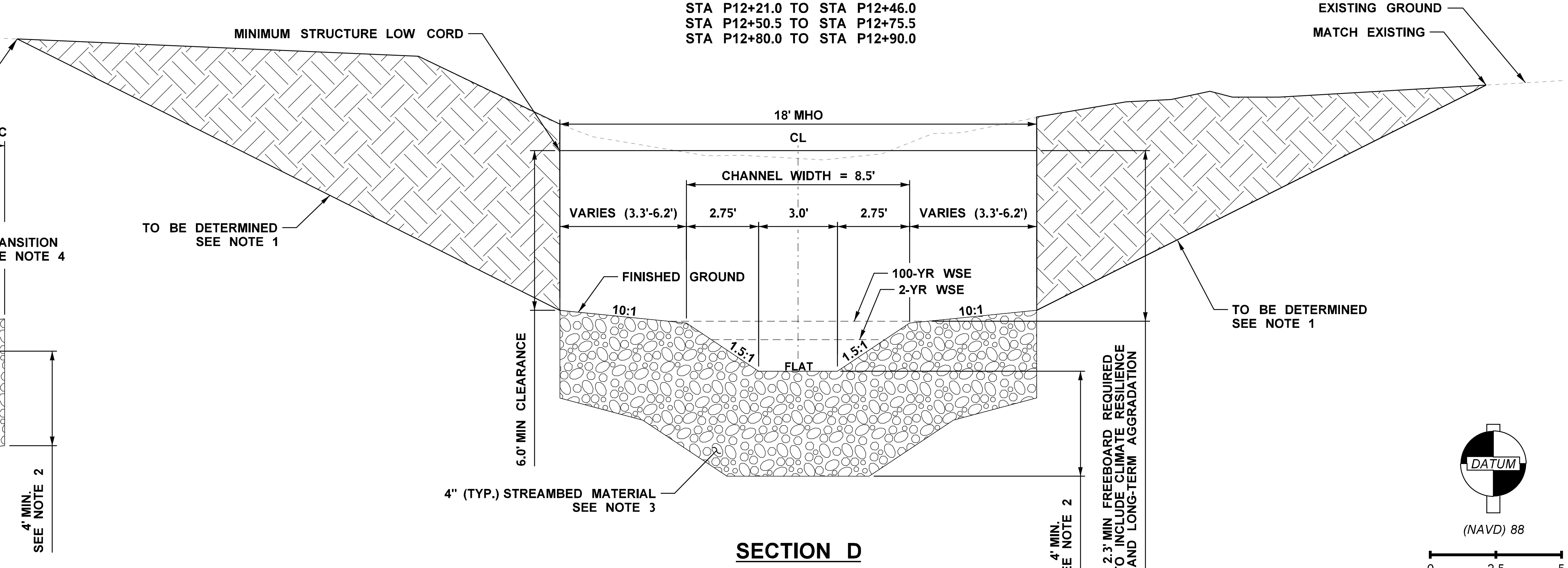


SECTION C
TYPICAL GLIDE INSIDE STRUCTURE

STA P12+00.0 TO STA P12+16.5
STA P12+21.0 TO STA P12+46.0
STA P12+50.5 TO STA P12+75.5
STA P12+80.0 TO STA P12+90.0



GLIDE TO POOL TRANSITION DETAIL BETWEEN SECTION C AND SECTION D



SECTION D
TYPICAL POOL INSIDE STRUCTURE

STA P12+17.5 TO STA P12+19.5
STA P12+47.0 TO STA P12+49.0
STA P12+76.5 TO STA P12+78.5

DATUM
(NAVD) 88

0 2.5 5
SCALE IN FEET (H)

0 2.5 5
SCALE IN FEET (V)

FILE NAME	c:\pwworking\jacobs_b&i\pw_wsdot\d0462822\991242_Proposed_CrossSection_2.dgn
TIME	1:59:25 PM
DATE	5/20/2022
PLOTTED BY	HollanRA
DESIGNED BY	R. HOLLAND
ENTERED BY	R. HOLLAND
CHECKED BY	K. WILLIAMS
PROJ. ENGR.	J. HEILMAN
REGIONAL ADM.	-

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER XL5467

CONTRACT NO. C9242

LOCATION NO.

PRELIMINARY
NOT FOR CONSTRUCTION

P.E. STAMP BOX DATE
P.E. STAMP BOX DATE

Washington State Department of Transportation

SR 3 MILE POST 57.23
991242 UNT TO KINMAN CREEK
FISH BARRIER REMOVAL

PROPOSED STREAM CROSS SECTION

PLAN REF NO CD2

SHEET 6 OF 6 SHEETS

Appendix E: Manning's Calculations

There are no Manning's Calculations for UNT to Kinman Creek at SR 3 MP 57.23.

Appendix F: Large Woody Material Calculations

WSDOT Large Woody Material for stream restoration metrics calculator

State Route# & MP	*SR3, MP 57.23*		**Key piece volume**	***1.310***	*yd3*
Stream name	*Trib to Kinman*		**Key piece/ft**	***0.0335***	*per ft stream*
length of regrade[a]	*219*	*ft*	**Total wood vol./ft**	***0.3948***	*yd3/ft stream*
Bankfull width	*6*	*ft*	**Total LWM**[c] **pieces/ft stream**	***0.1159***	*per ft stream*
Habitat zone[b]	*Western WA*				

Taper coeff.	-0.01554
LF_{rw}	1.5
H_{dbh}	4.5

yes

no

Log type	*Diameter at midpoint (ft)*	*Length(ft)*[d]	*Volume (yd^3/log)*[d]	*Rootwad?*	*Qualifies as key piece?*	*No. LWM pieces*	*Total wood volume (yd^3)*	DBH based on mid point diameter (ft)	$D_{root\ collar}$ (ft)	L/2-Lrw (ft)
A	2.39	*30*	4.98	**yes**	yes	6	29.91	2.50	2.57	11.415
B	1.70	*20*	1.68	**yes**	yes	8	13.45	1.75	1.82	7.45
C	1.15	*12.5*	0.48	**no**	no	10	4.81	1.25	1.22	4.525
D	0.94	*8*	0.21	**no**	no	10	2.06	1.00	0.98	2.59
E			0.00				0.00		0.00	0
F			0.00				0.00		0.00	0
G			0.00				0.00		0.00	0
H			0.00				0.00		0.00	0
I			0.00				0.00		0.00	0
J			0.00				0.00		0.00	0
K			0.00				0.00		0.00	0
L			0.00				0.00		0.00	0
M			0.00				0.00		0.00	0
N			0.00				0.00		0.00	0
O			0.00				0.00		0.00	0
P			0.00				0.00		0.00	0

Log volume for stability calcs (yd^3, per log)	
rootwad	bole
2.07	4.39
0.74	1.47
0.00	0.48
0.00	0.21
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00

	No. of key pieces	Total No. of LWM pieces	Total LWM volume (yd^3)[3]
Design	14	34	50.2
Targets	**7**	**25**	**86.5**
	surplus	surplus	deficit

[a] **includes length through crossing, regardless of structure type**

[b] **choose one of the following Forest Regions in the drop-down menu (if in doubt ask HQ Biology). See also the Forest Region tab for additional information**

Western Washington lowl (generally <4,200 ft. in elevation west of the Cascade Crest)
Alpine (generally > 4,200 ft. in elevation and down to ~3,700 ft. in elevation east of the Cascade crest)
Douglas fir-Ponderosa pin (mainly east slope Cascades below 3,700 ft. elevation)

[c] **LWM (Large Woody Material), also known as LWD (Large Woody Debris) is defined as a piece of wood at least 10 cm (4") diam. X 2 m (6ft) long (Fox 2001).**

[d] **includes rootwad if present**

Key piece volume	
BFW class (ft)	volume (yd3)
0-16	1.31
17-33	3.28
34-49	7.86
50-66	11.79
67-98	12.77
99-164	13.76
165-328	14.08

adapted from Fox and Bolton (2007), Table 5

Key Piece density lookup table		
Habitat zone	BFW class (feet)	75th percentile (yd3/ft stream)
Western WA	0-33	0.0335
	34-328	0.0122
Alpine	0-49	0.0122
	50-164	0.0030
Douglas Fir/Pond. Pine (much of eastern WA)	0-98	0.0061

adapted from Fox and Bolton (2007), Table 4

Total Wood Volume lookup table		
Habitat zone	BFW class (feet)	75th percentile (yd3/ft stream)
Western WA	0-98	0.3948
	99-328	1.2641
Alpine	0-10	0.0399
	11-164	0.1196
Douglas Fir/Pond. Pine	0-98	0.0598

adapted from Fox and Bolton (2007), Table 4

Number of LWM pieces lookup table		
Habitat zone	BFW class (feet)	75th percentile (per/ft stream)
Western WA	0-20	0.1159
	21-98	0.1921
	99-328	0.6341
Alpine	0-10	0.0854
	11-98	0.1707
	99-164	0.1921
Douglas Fir/Pond.	0-20	0.0884
	21-98	0.1067

adapted from Fox and Bolton (2007), Table 4

Appendix G: Future Projections for Climate-Adapted Culvert Design

Future Projections for Climate-Adapted Culvert Design

Project Name: 991242

Stream Name: UNT to Kinman

Drainage Area: 351 ac

Projected mean percent change in bankfull flow:

2040s: 13.3%

2080s: 16%

Projected mean percent change in bankfull width:

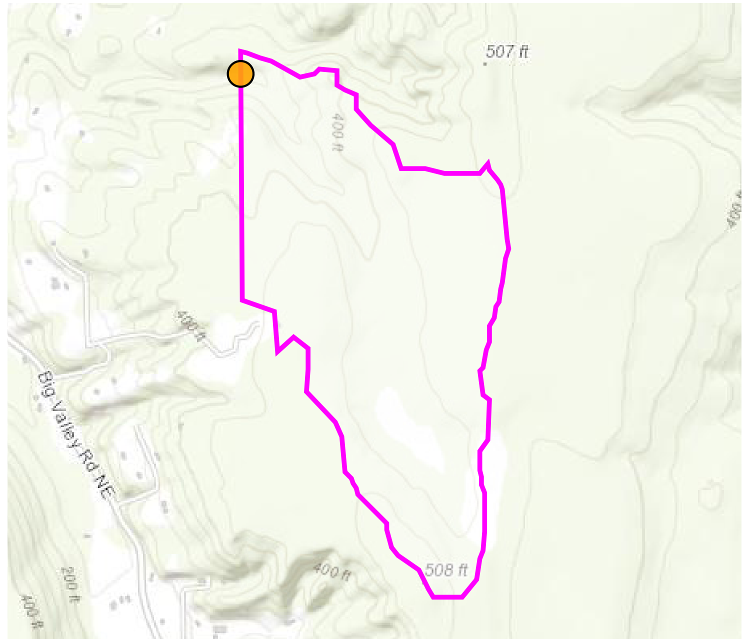
2040s: 6.4%

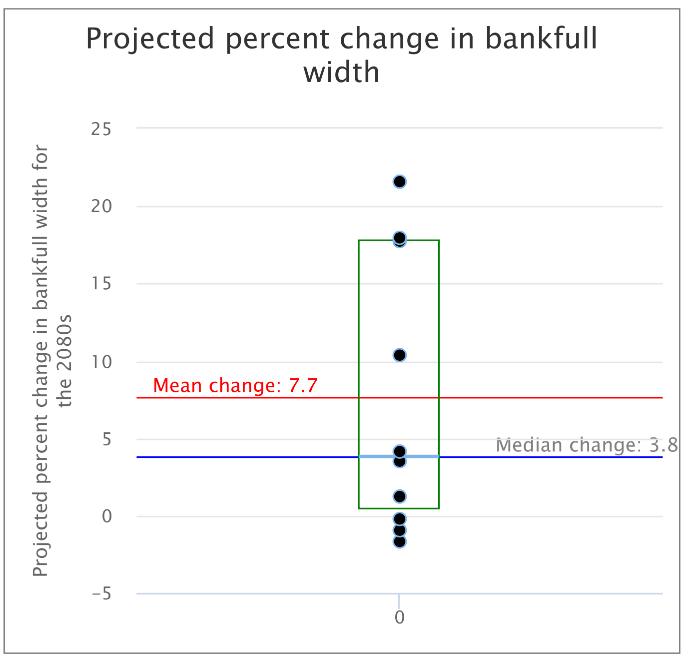
2080s: 7.7%

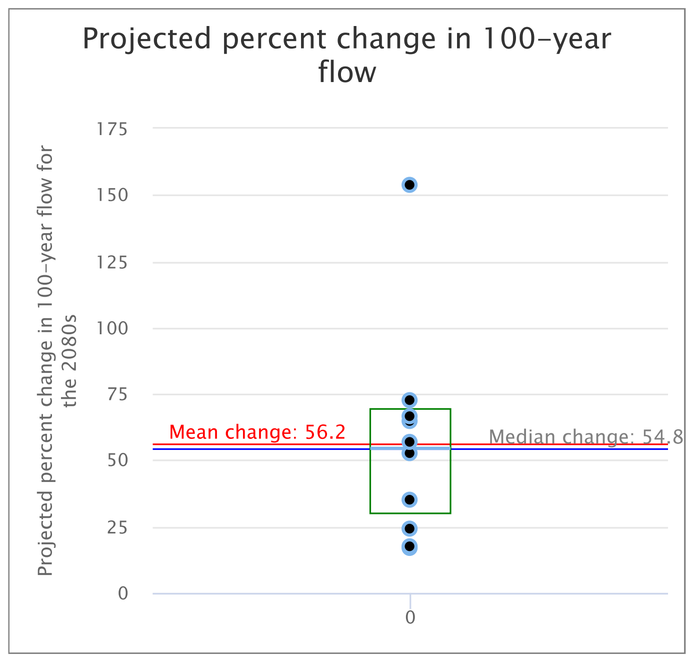
Projected mean percent change in 100-year flood:

2040s: 38.2%

2080s: 56.2%

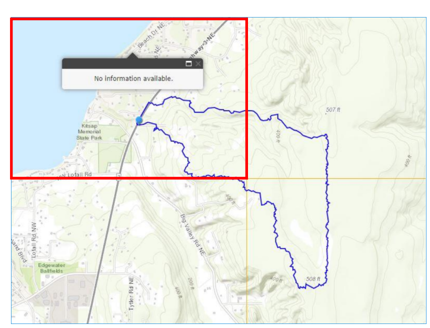






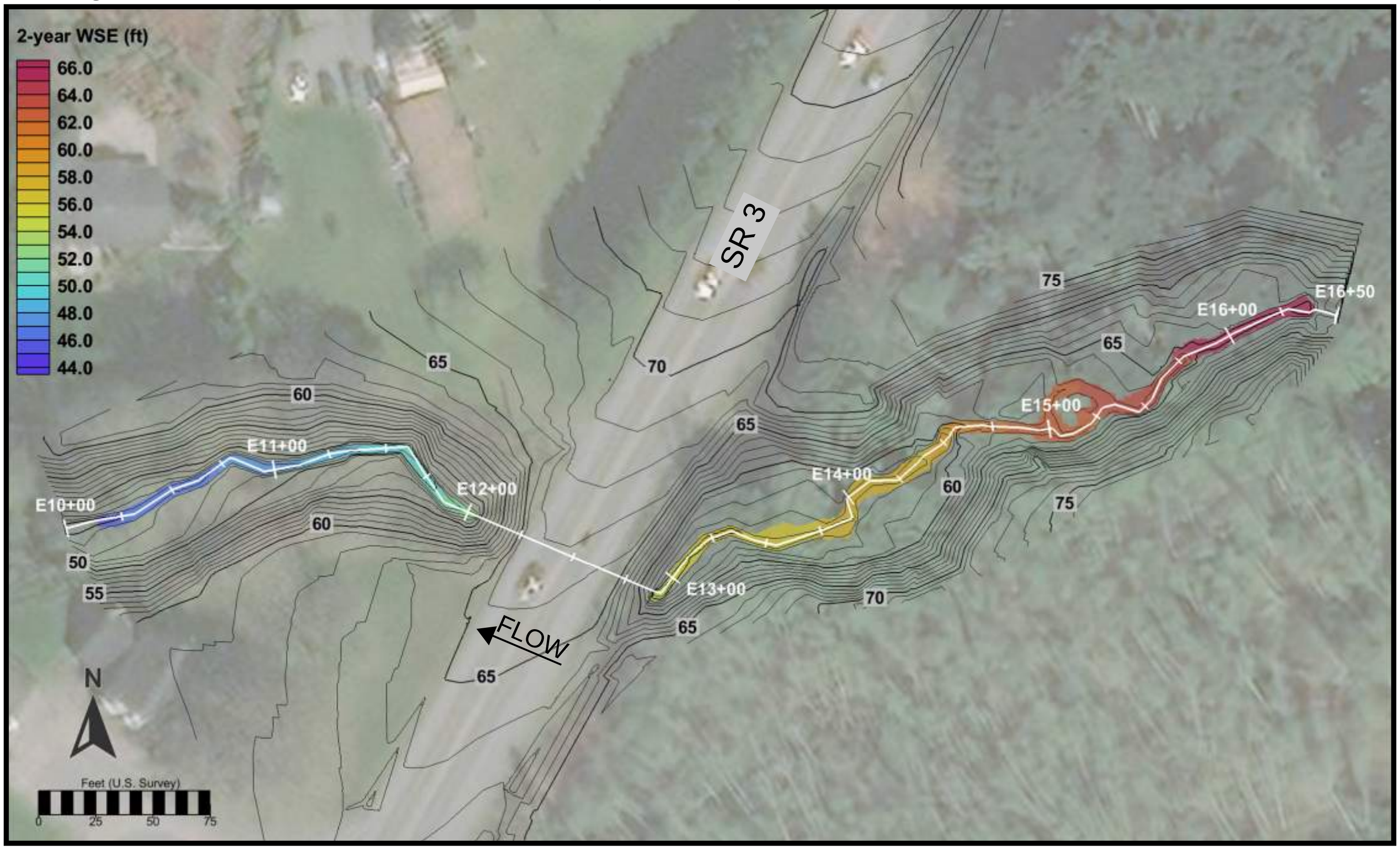
Black dots are projections from 10 separate models

Note: The Culverts and Climate Change app calculates projections based on gridded data. Where watersheds intersect multiple grid cells, the weighted average is calculated. The watershed for this site spans an empty grid cell and a grid cell with data. Reports cannot be exported for grid cells with no data, therefore this report is generated from a reduced watershed developed in the grid cell with data. The area in the report is not representative of the area of the site basin, but the reduction in area does not affect the projections in the report

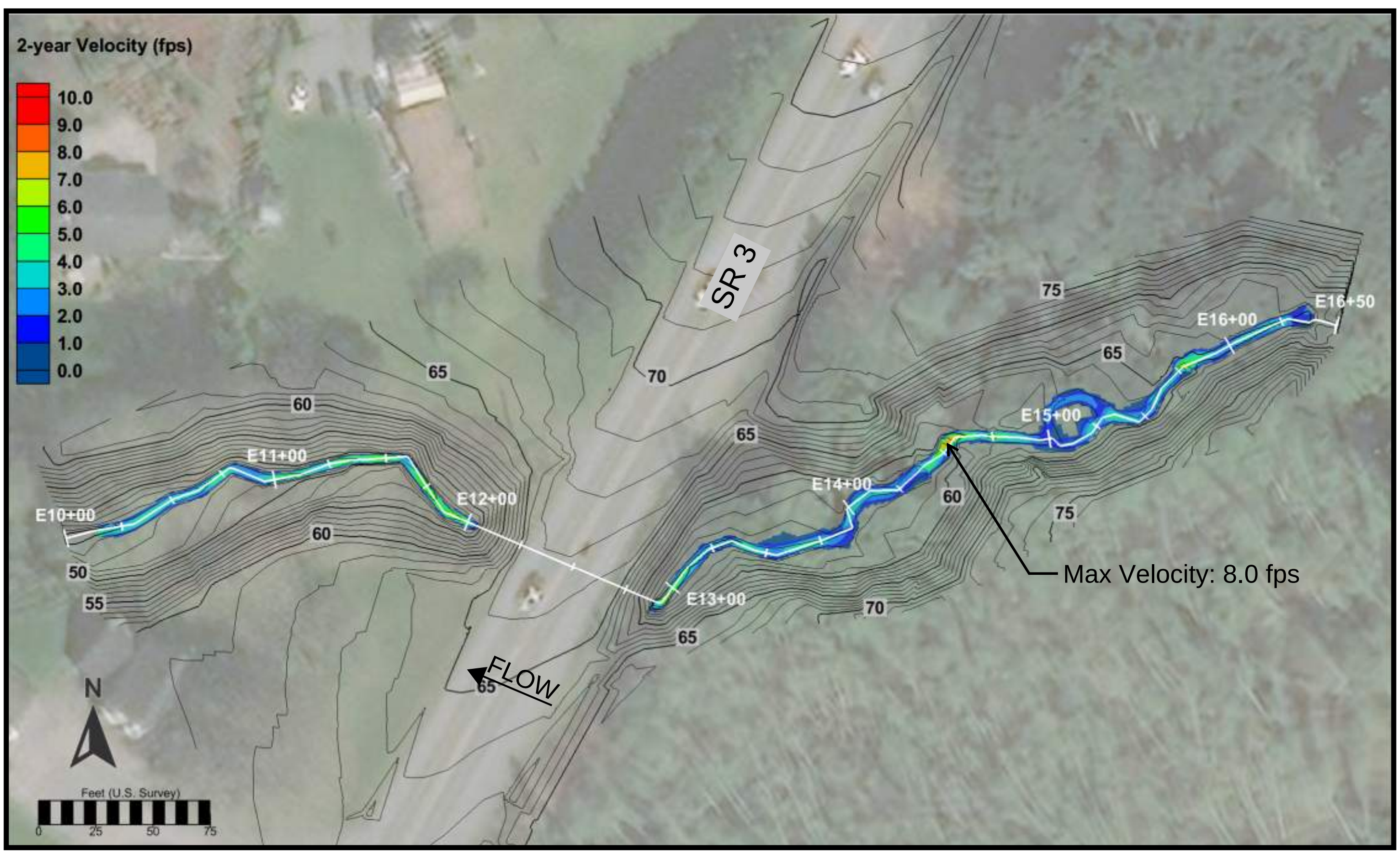


Appendix H: SRH-2D Model Results

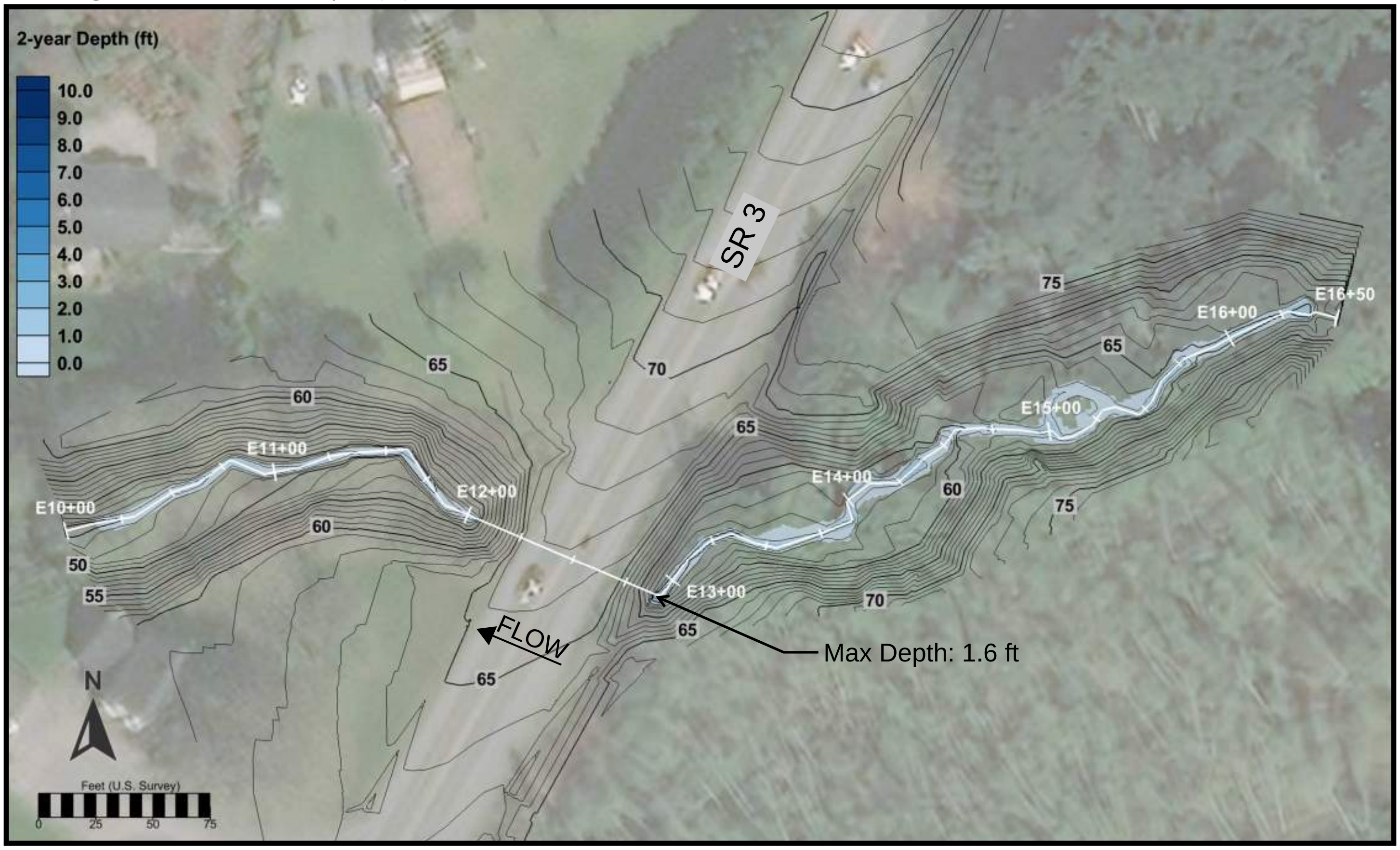
Existing Condition — Q2 Water Surface Elevations (ft, NAVD 88)



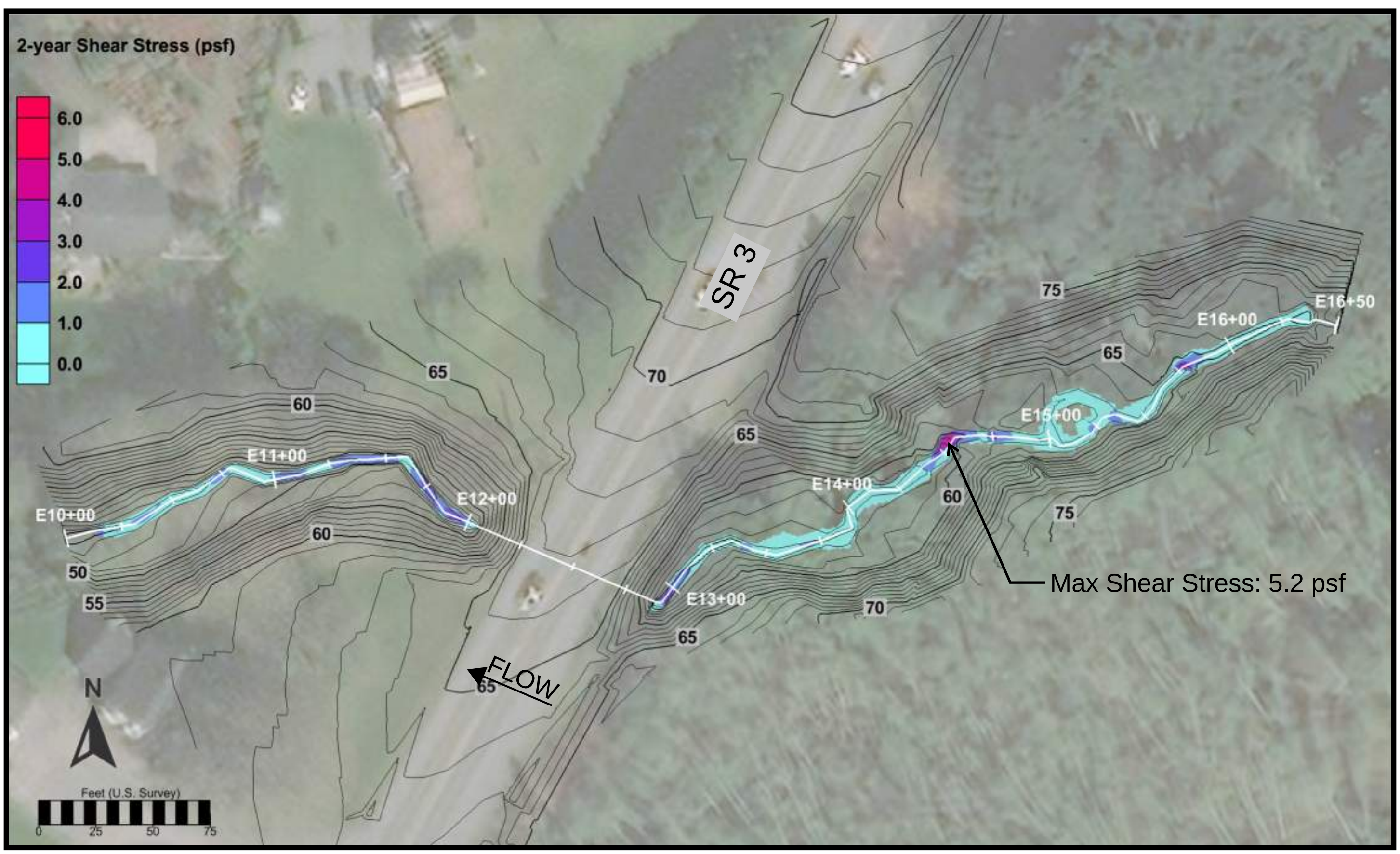
Existing Condition—Q2 Velocity (fps)



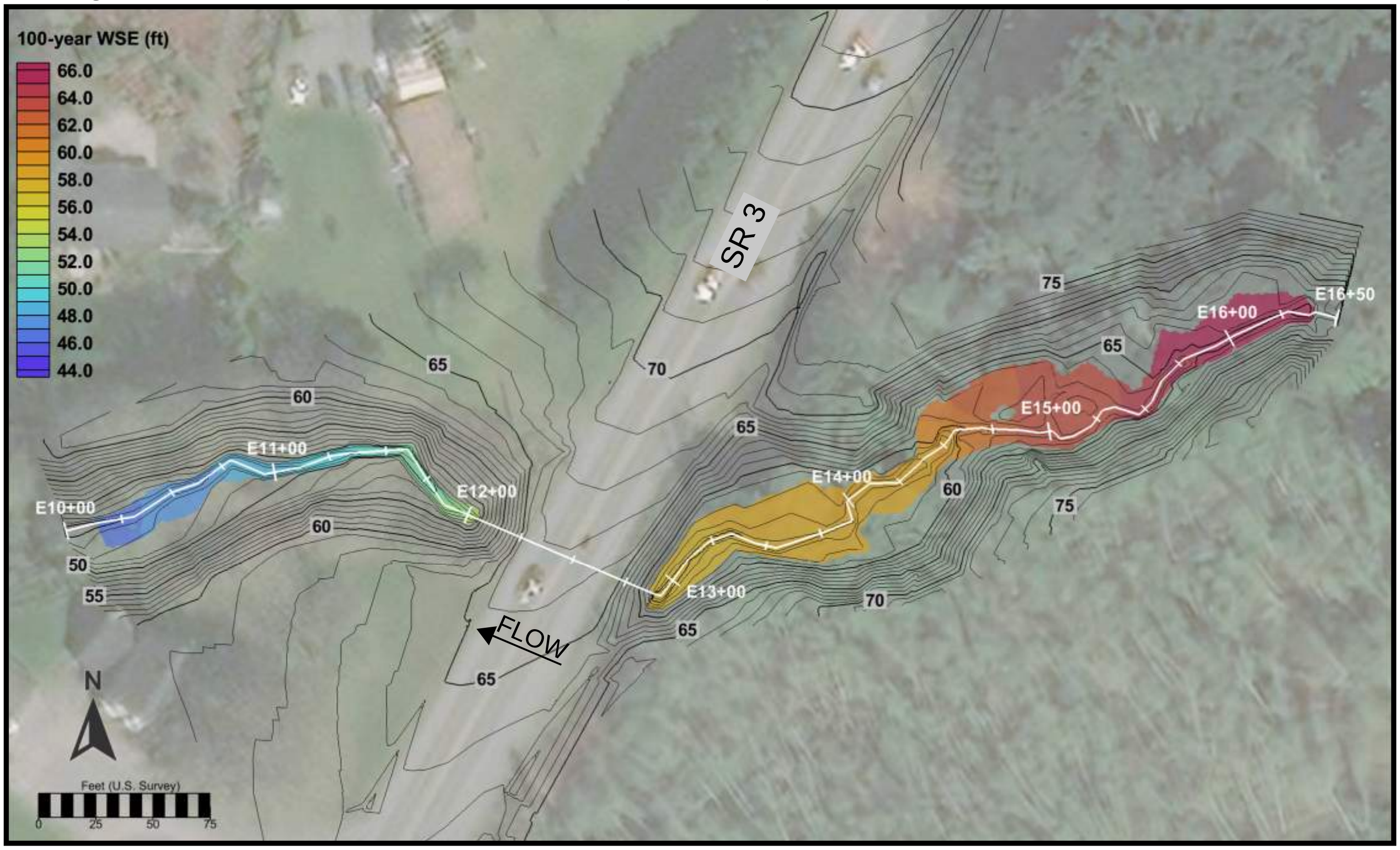
Existing Condition — Q2 Depth (ft)



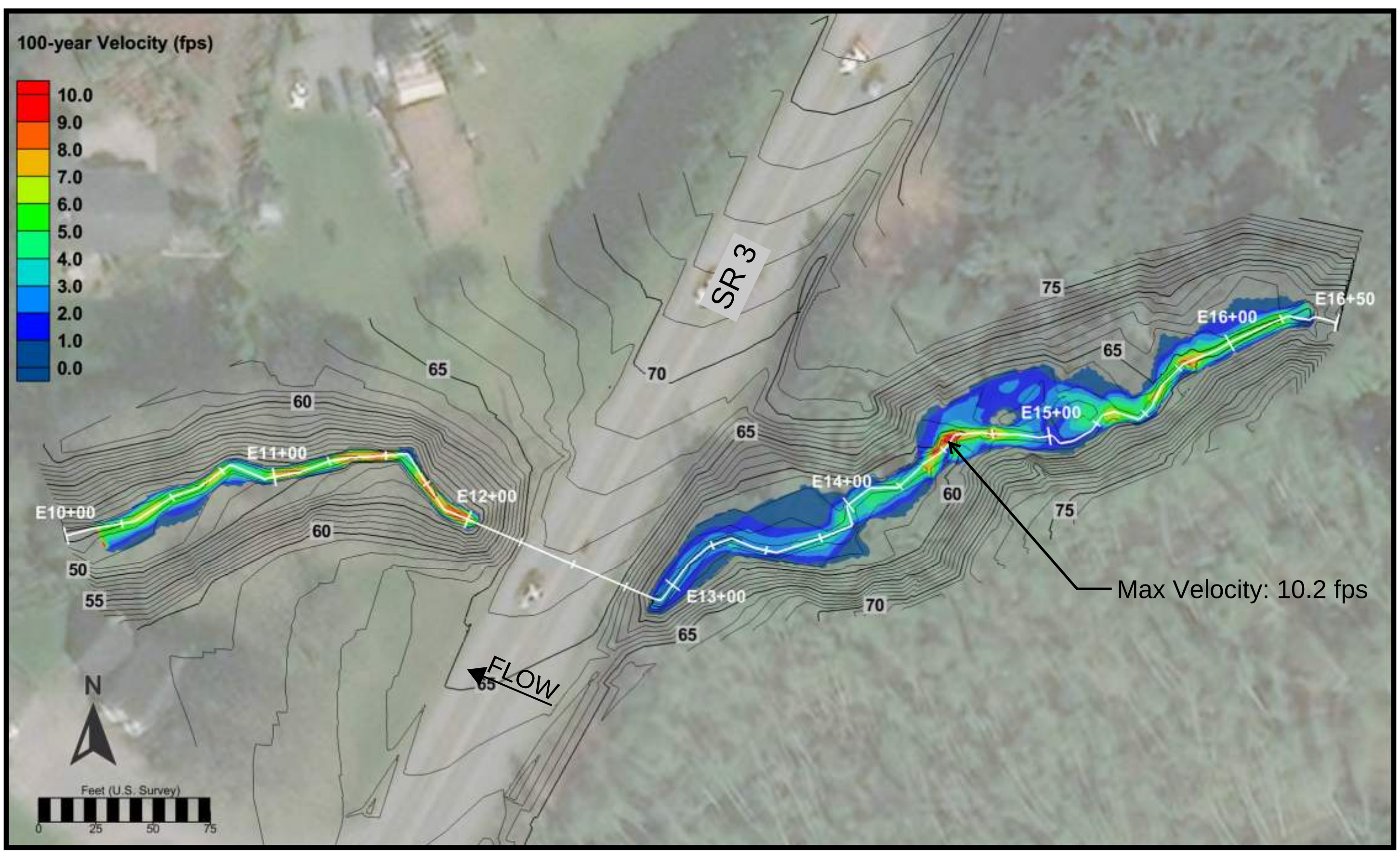
Existing Condition—Q2 Shear Stress (psf)



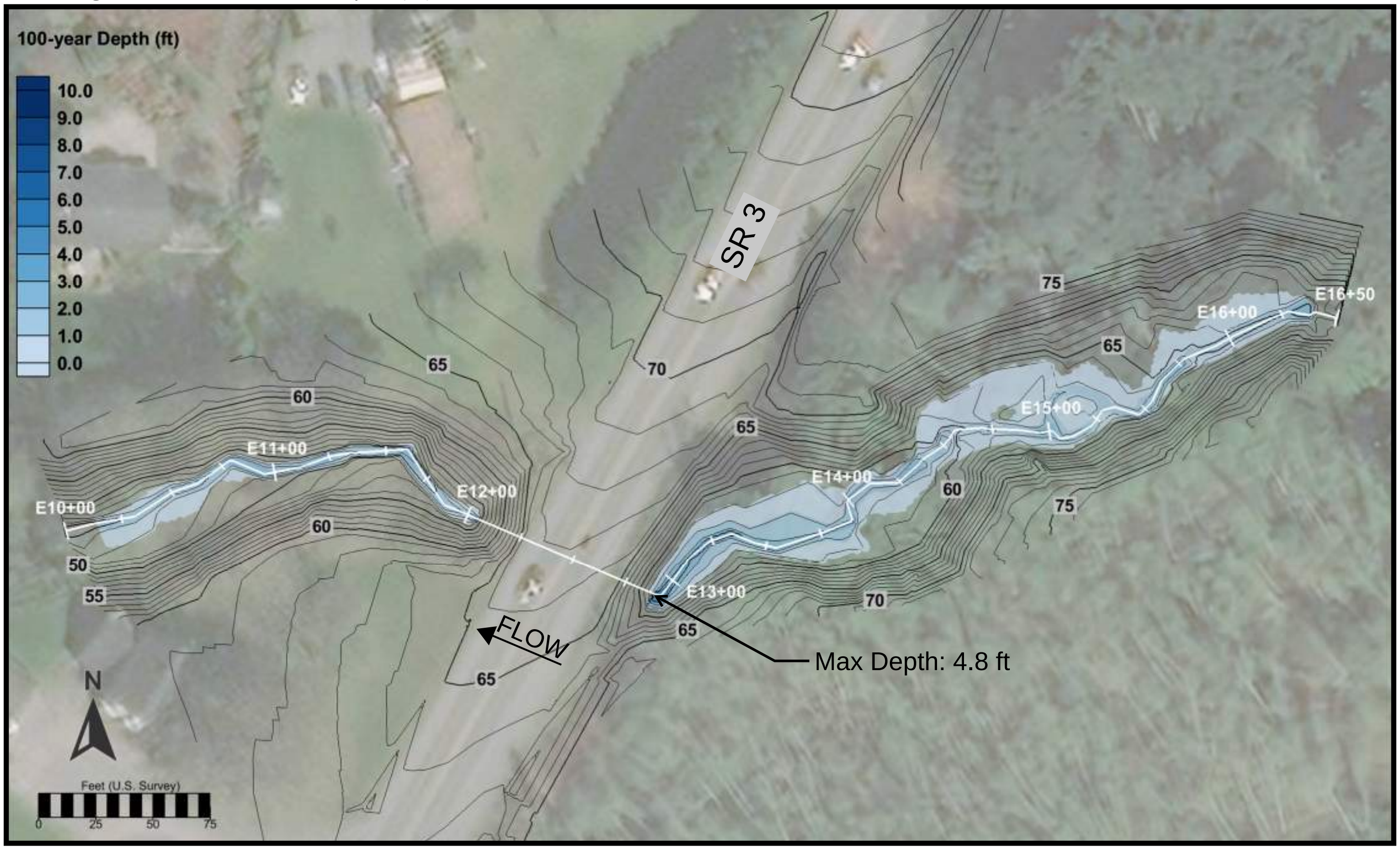
Existing Condition — Q100 Water Surface Elevations (ft, NAVD 88)



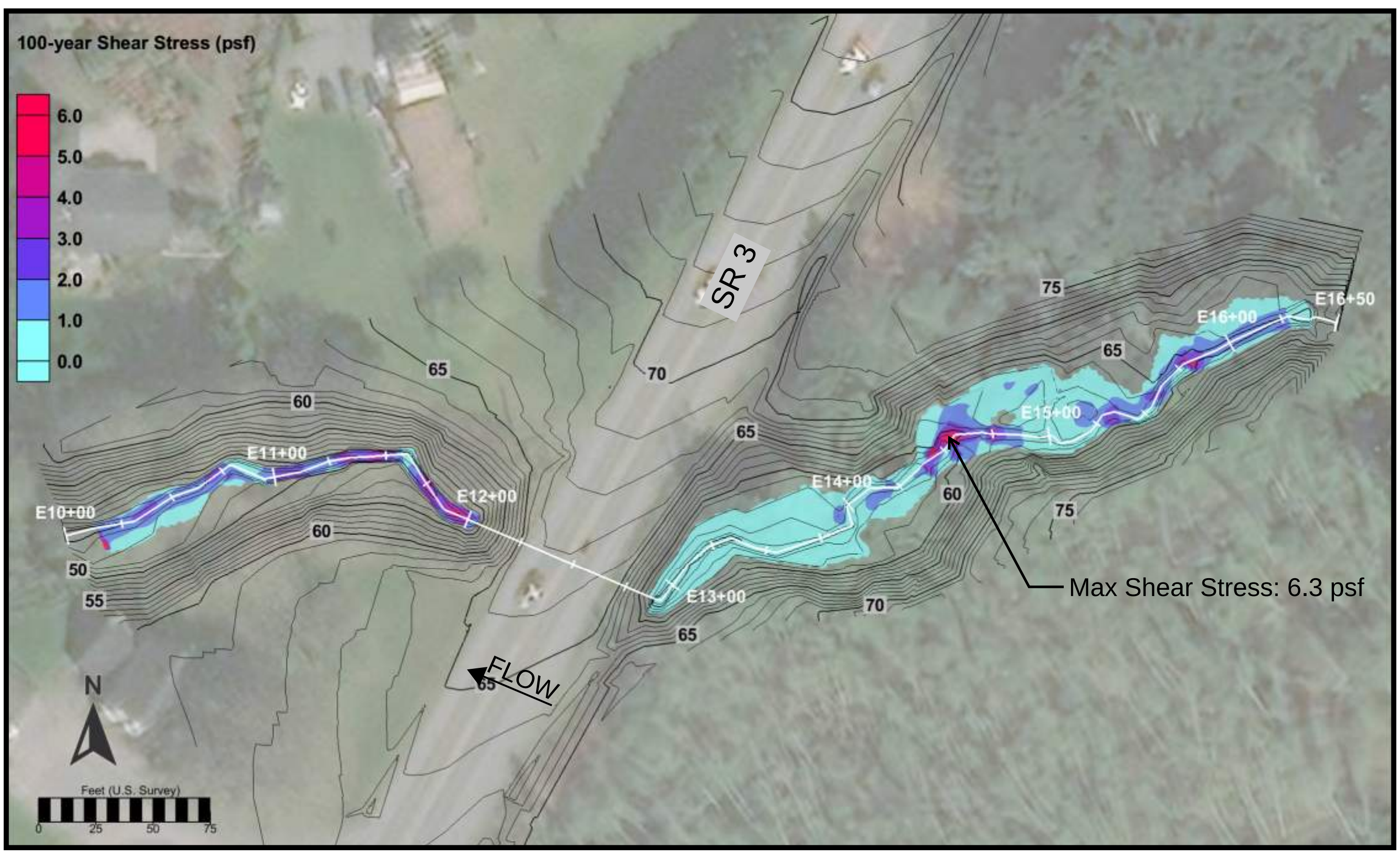
Existing Condition — Q100 Velocity (fps)



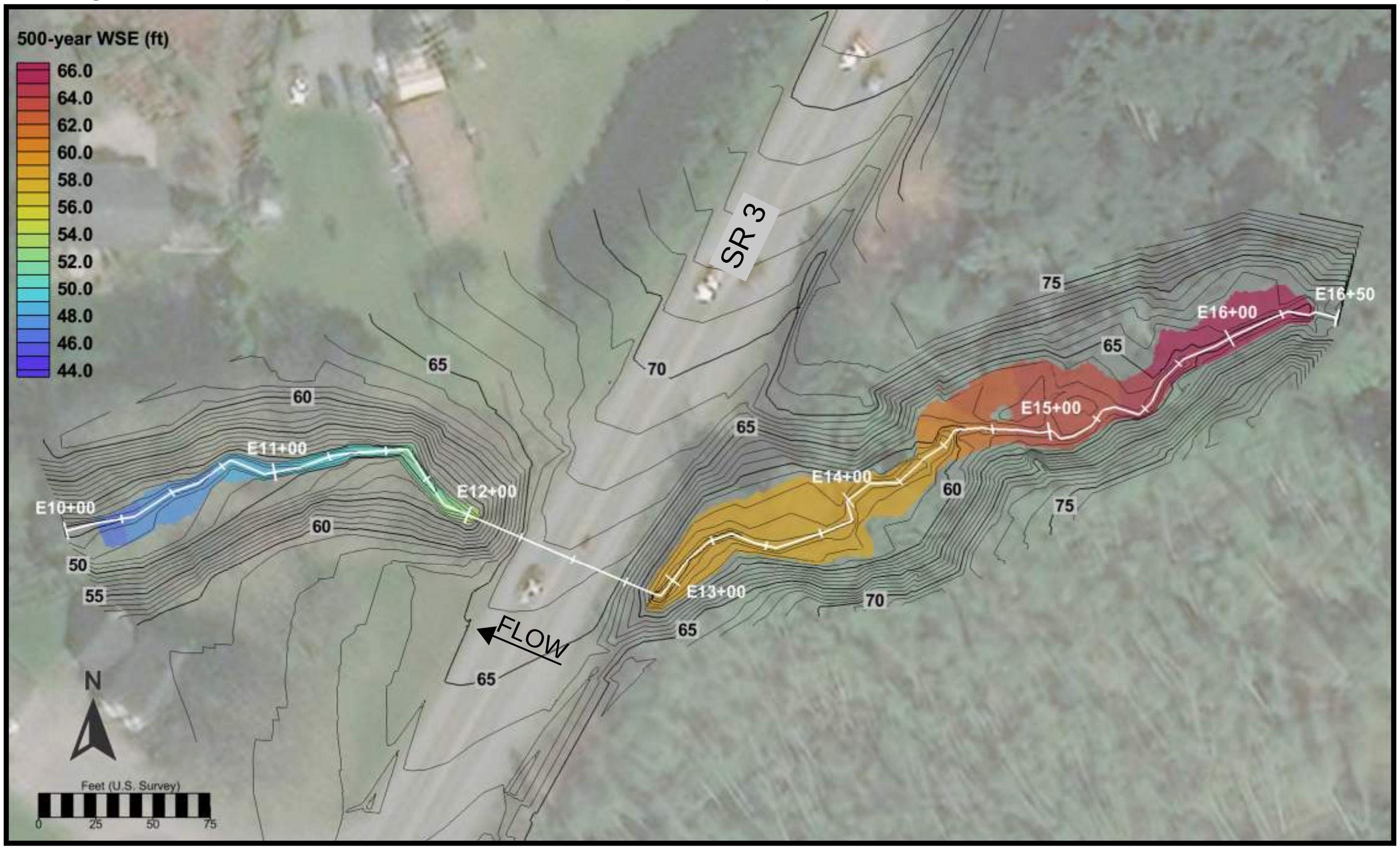
Existing Condition— Q100 Depth (ft)



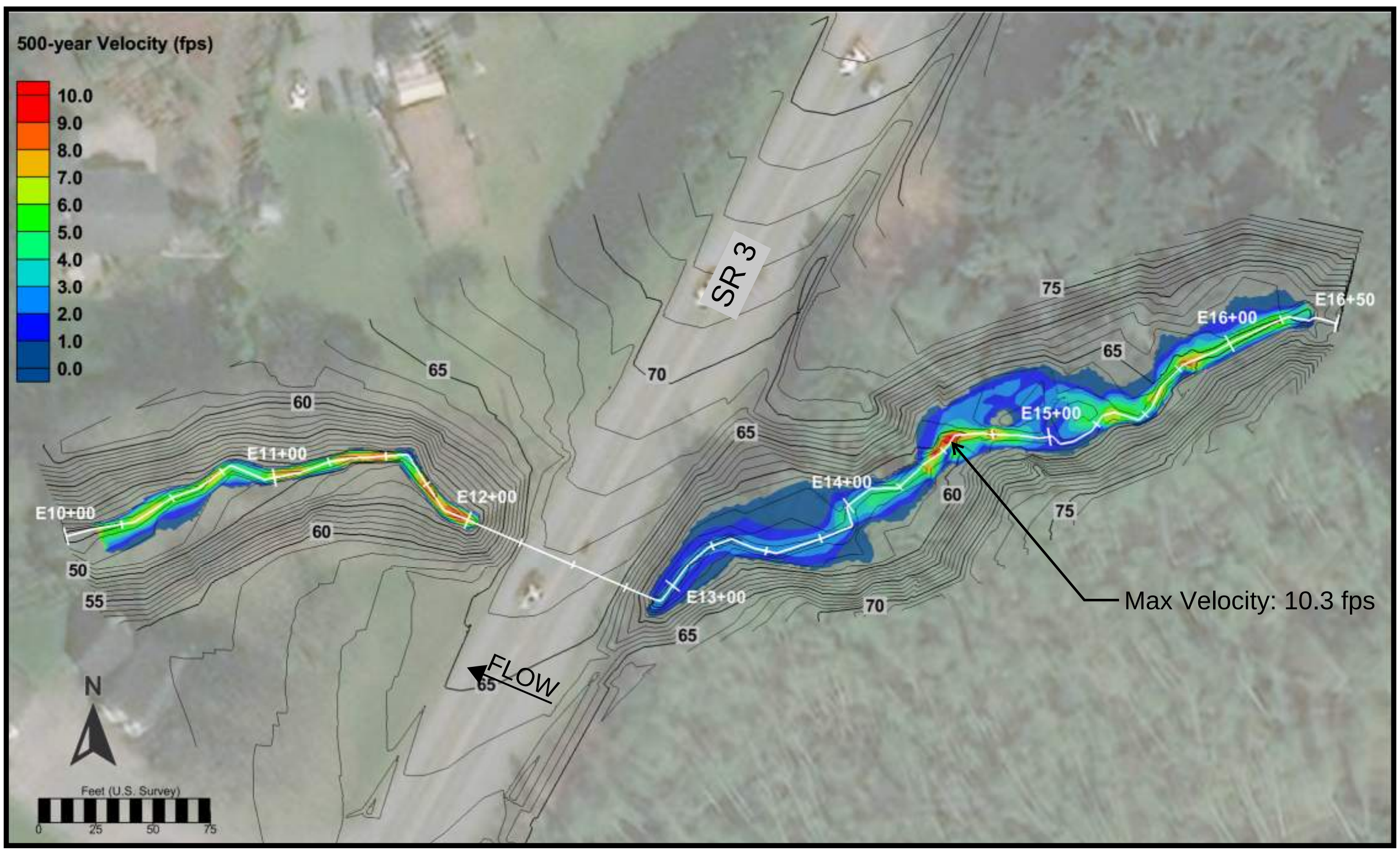
Existing Condition— Q100 Shear Stress (psf)



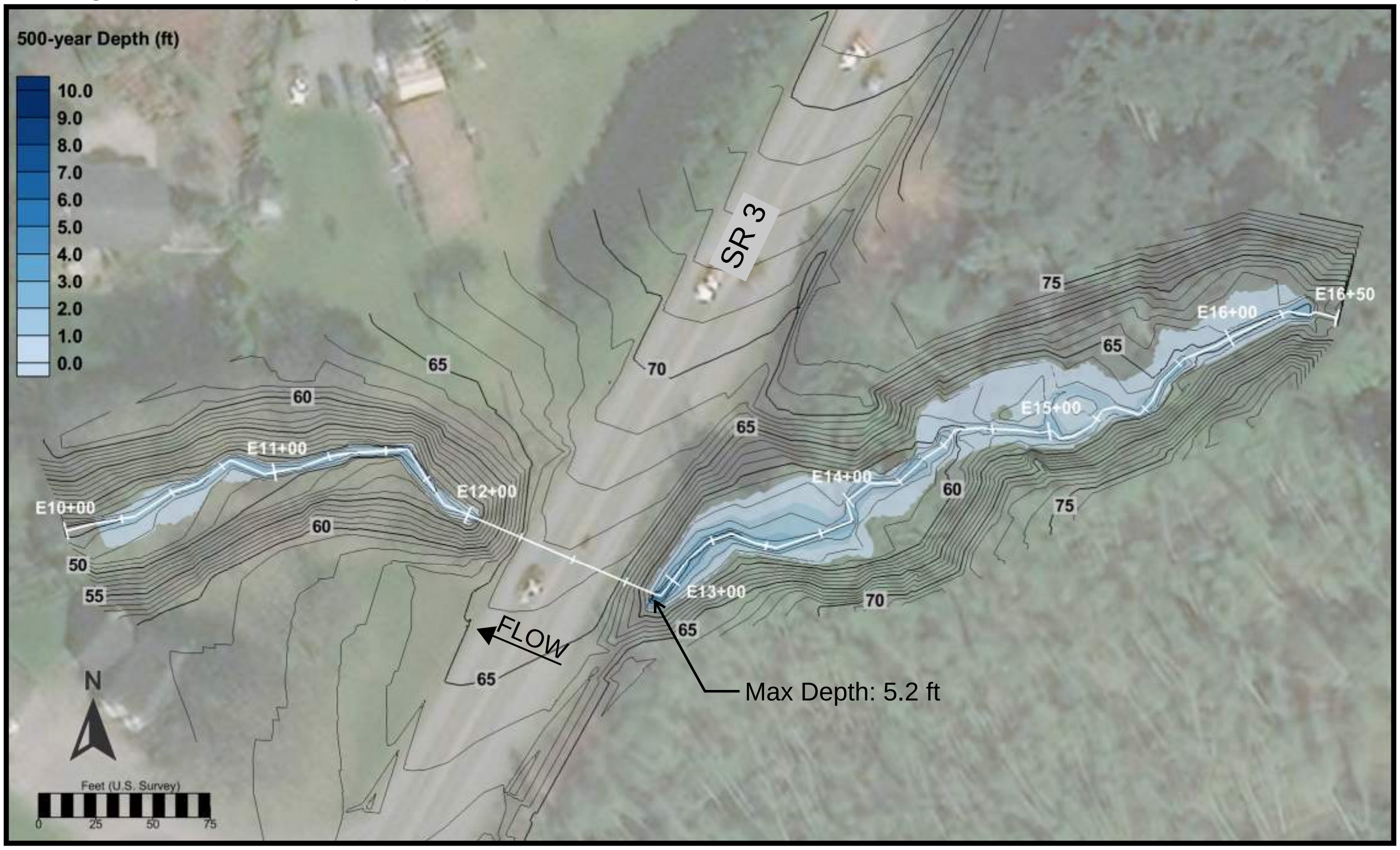
Existing Condition — Q500 Water Surface Elevations (ft, NAVD 88)



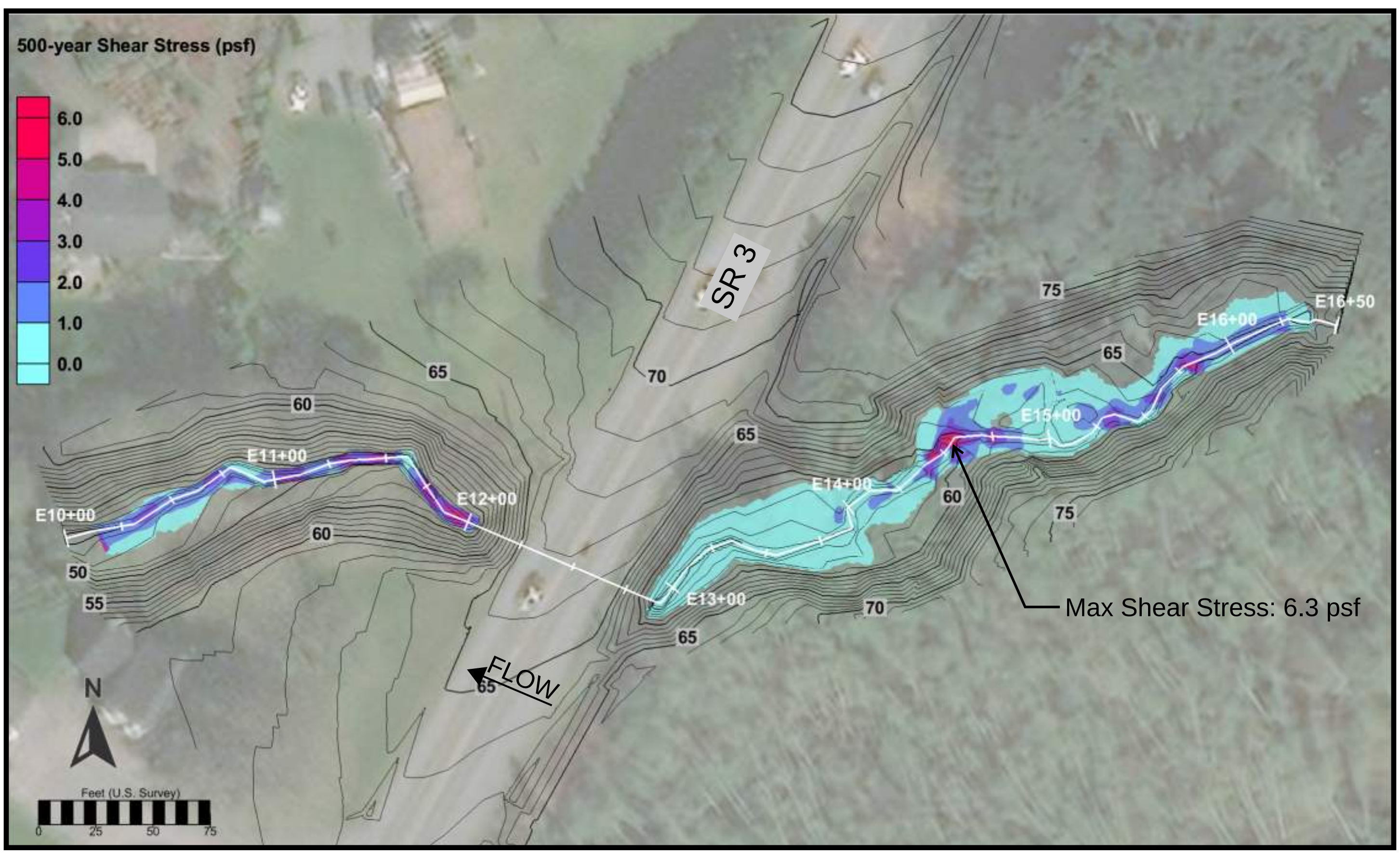
Existing Condition — Q500 Velocity (fps)



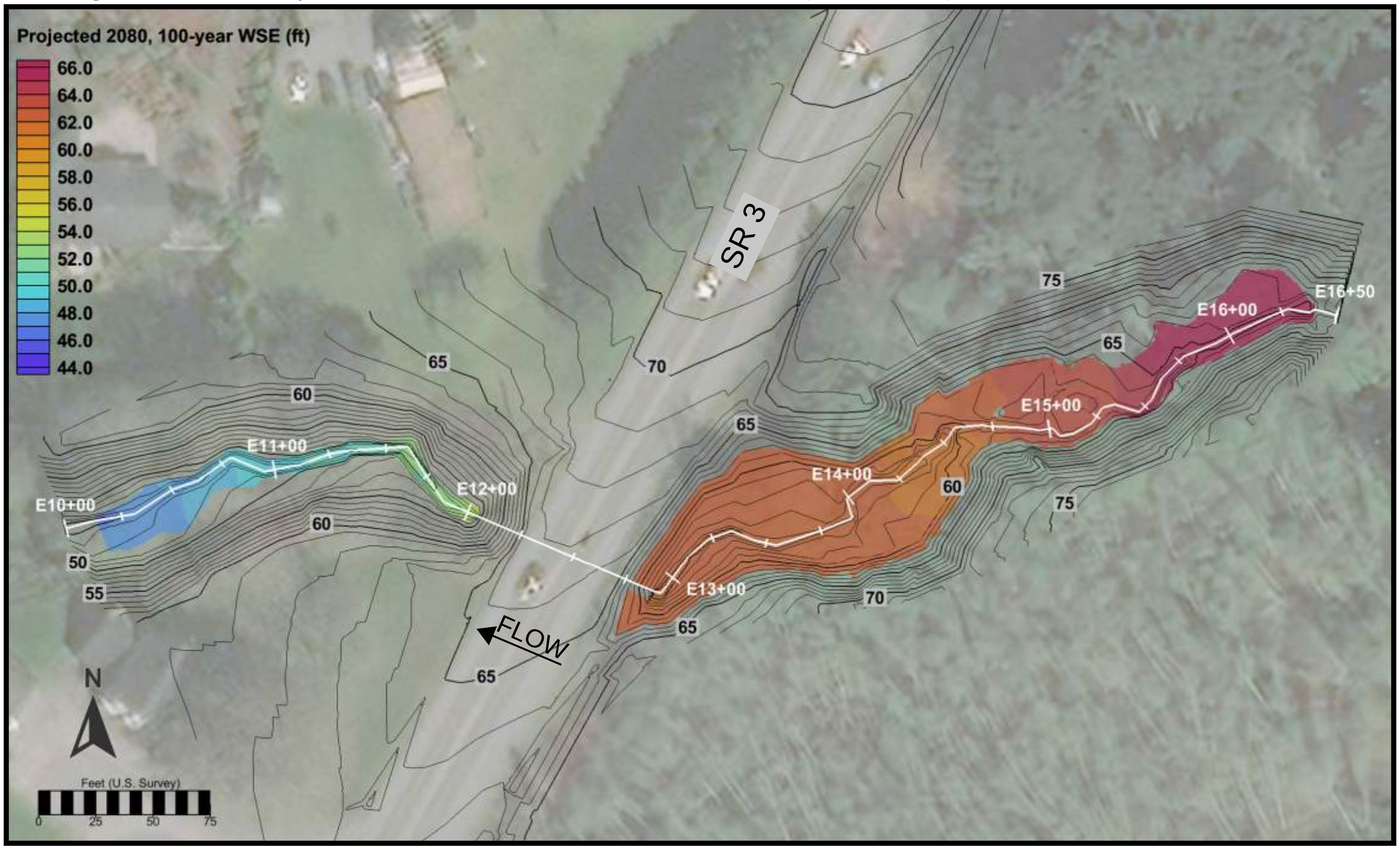
Existing Condition— Q500 Depth (ft)



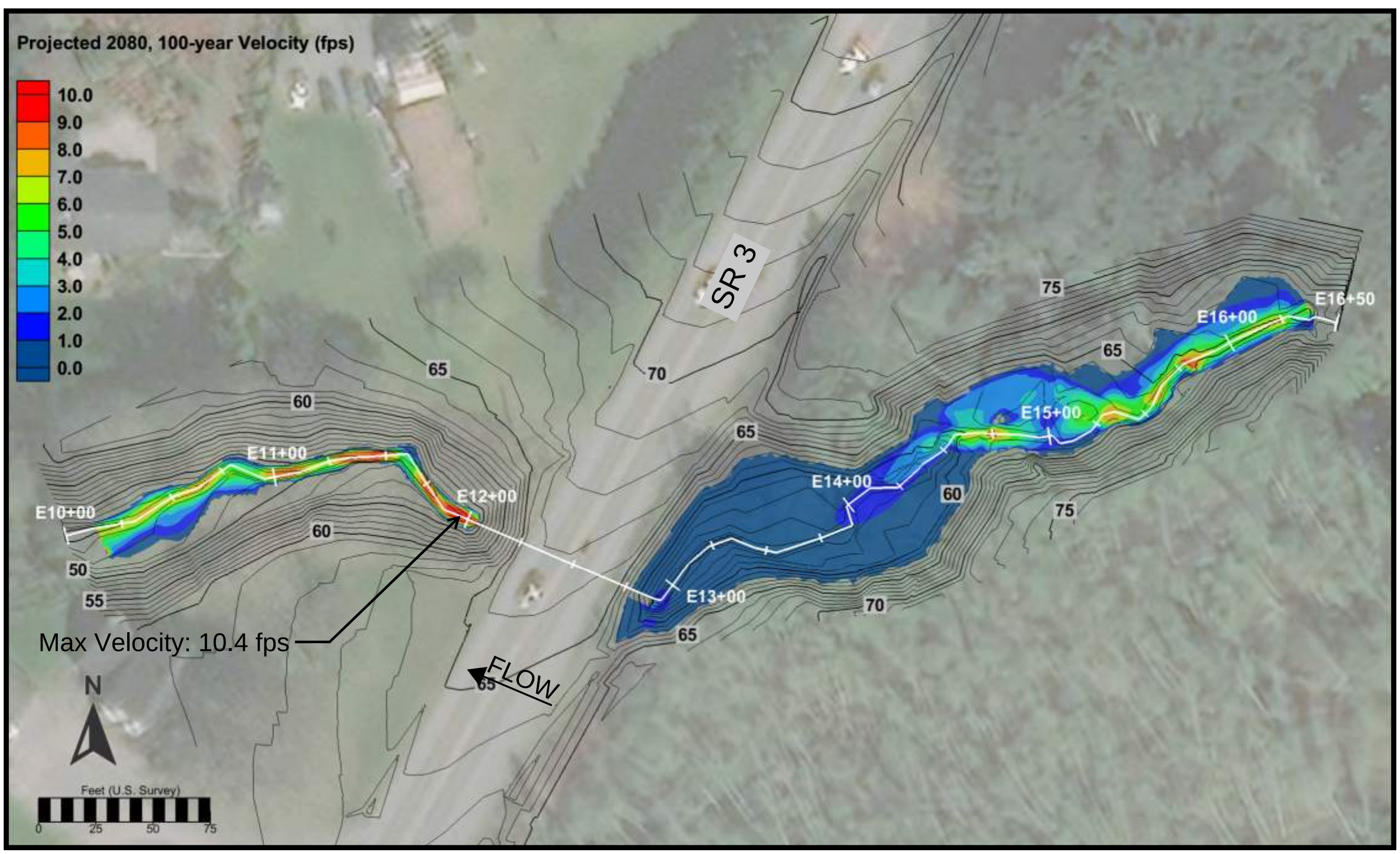
Existing Condition— Q500 Shear Stress (psf)



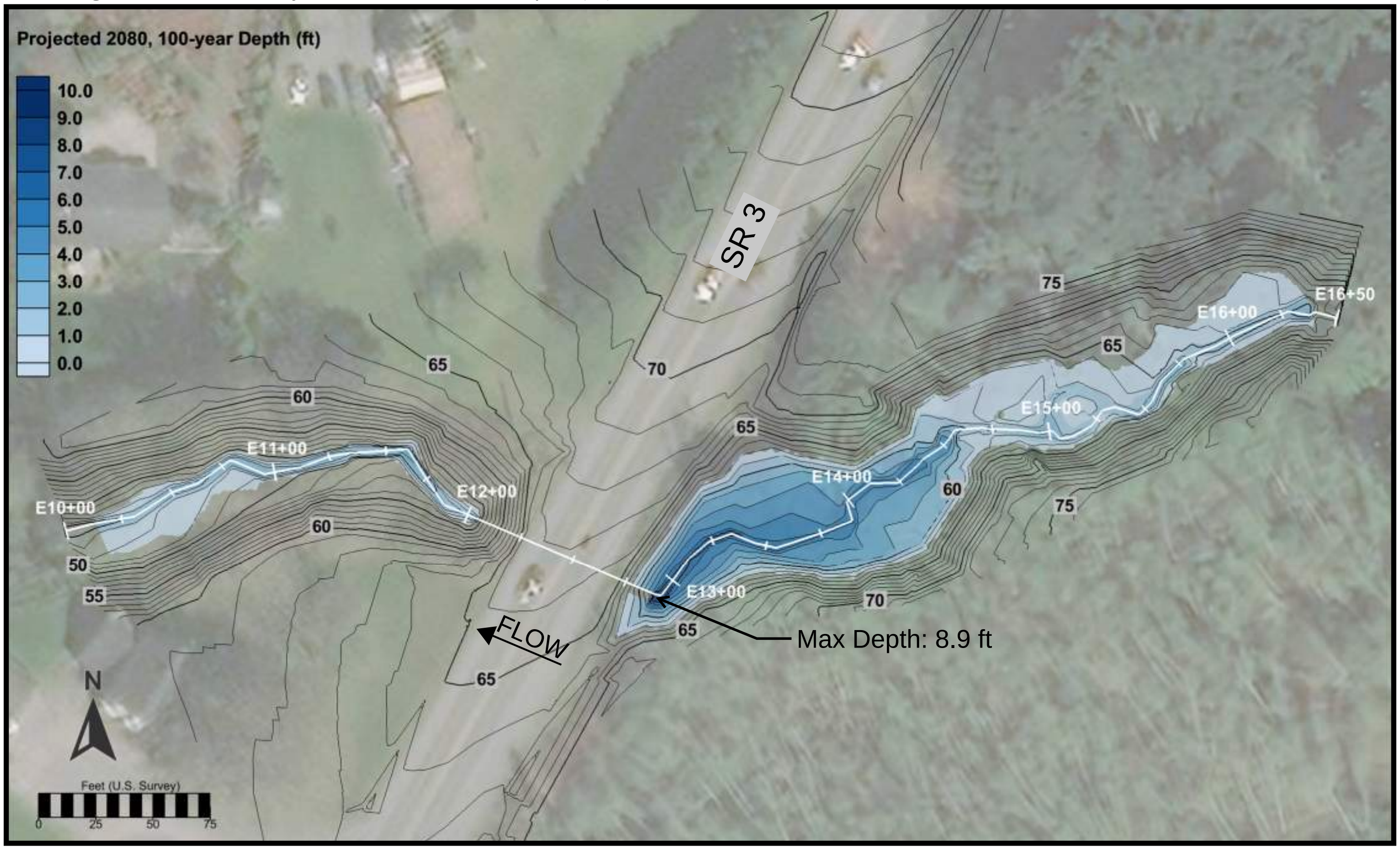
Existing Condition — Projected 2080 Q100 Water Surface Elevations (ft, NAVD 88)



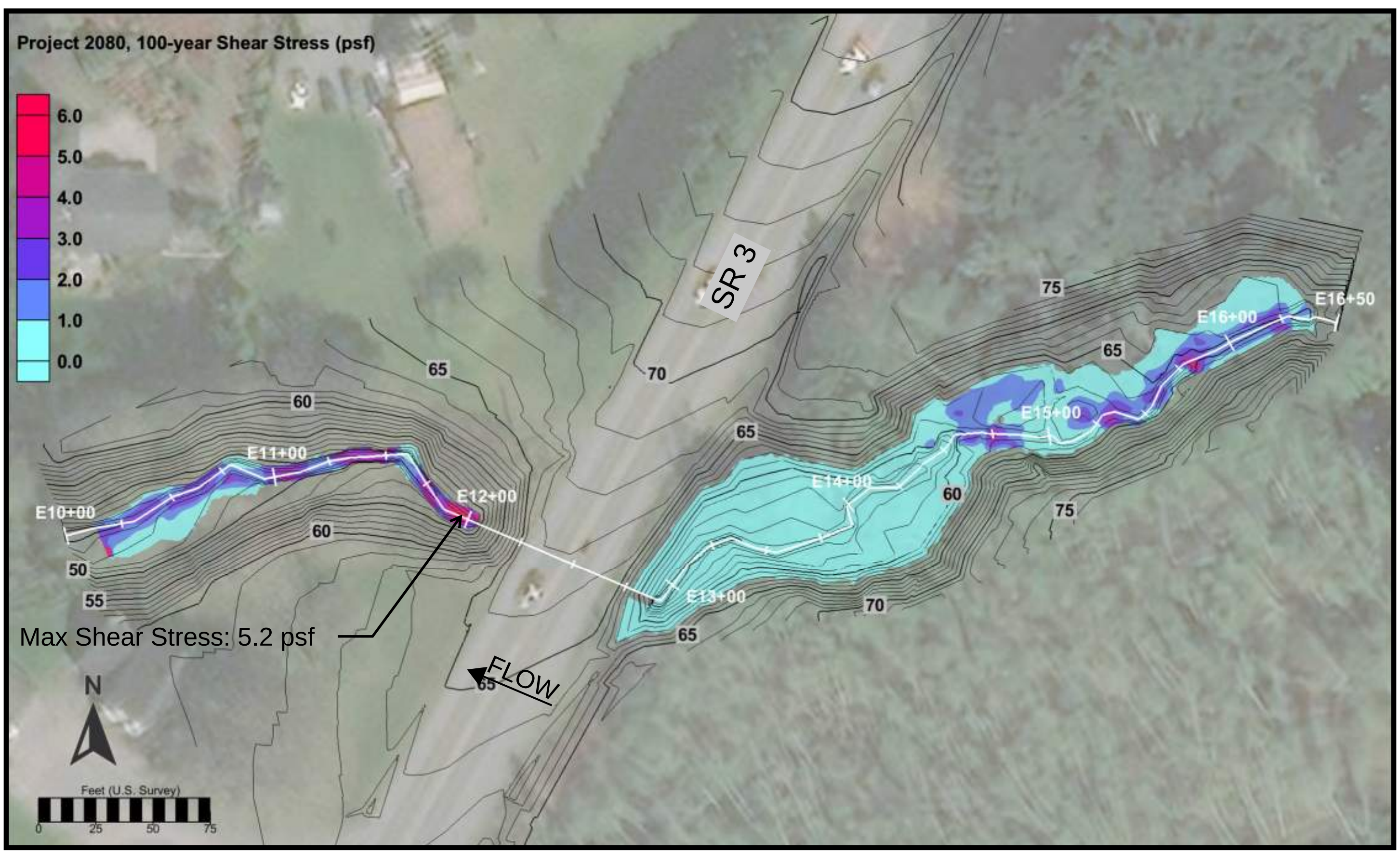
Existing Condition — Projected 2080 Q100 Velocity (fps)



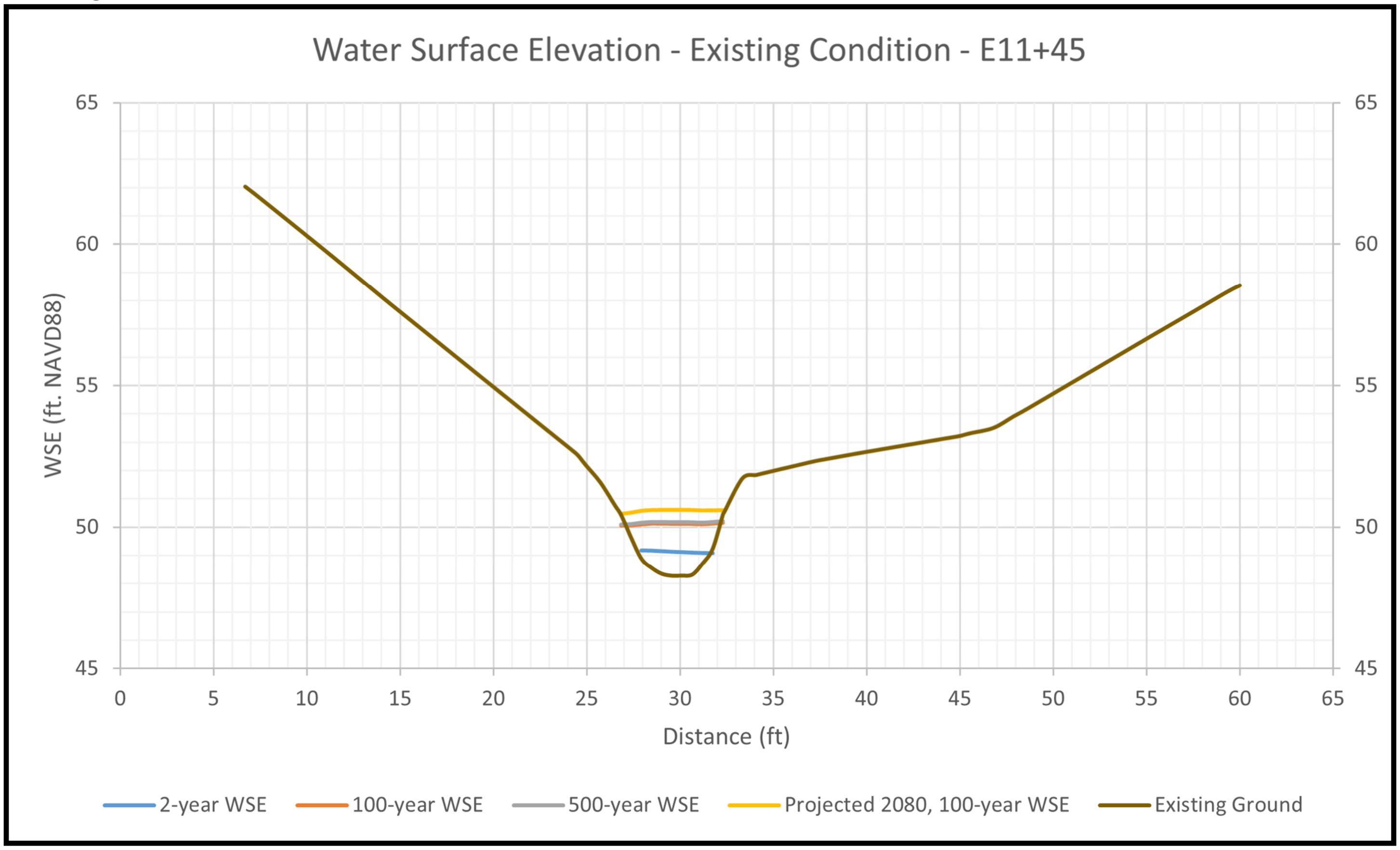
Existing Condition— Projected 2080 Q100 Depth (ft)



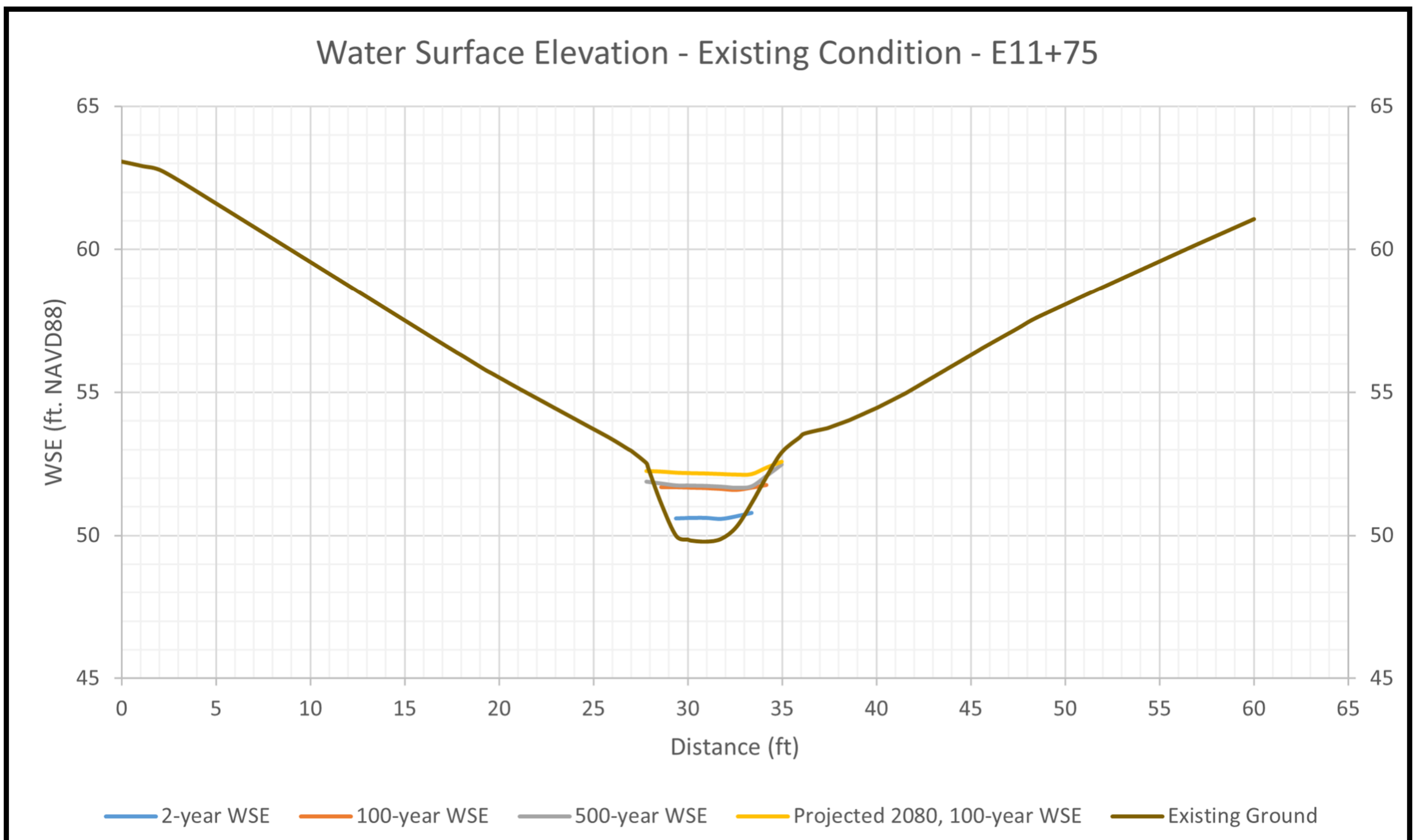
Existing Condition— Projected 2080 Q100 Shear Stress (psf)



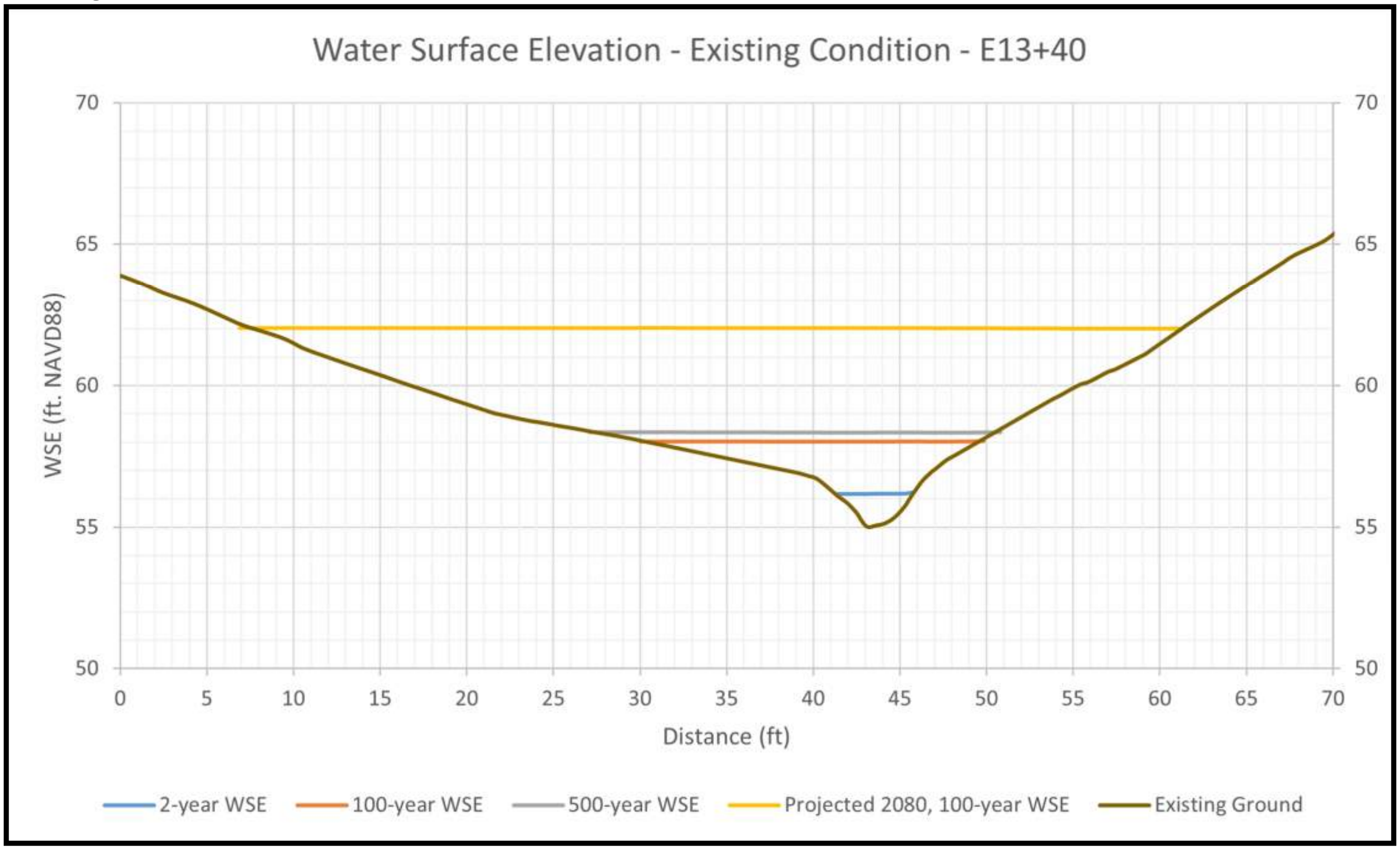
Existing Condition Section — Station E11+45



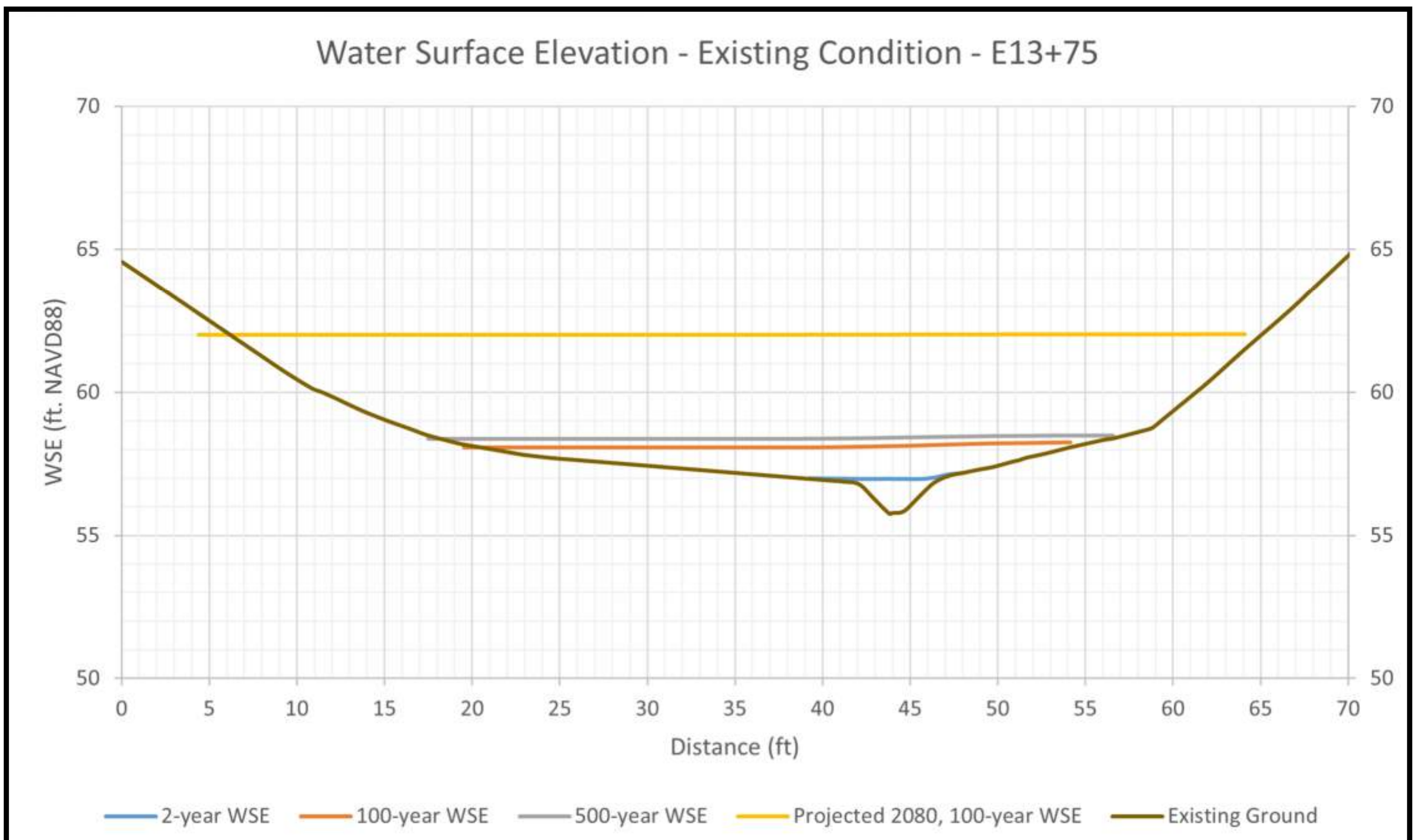
Existing Condition Section — Station E11+75



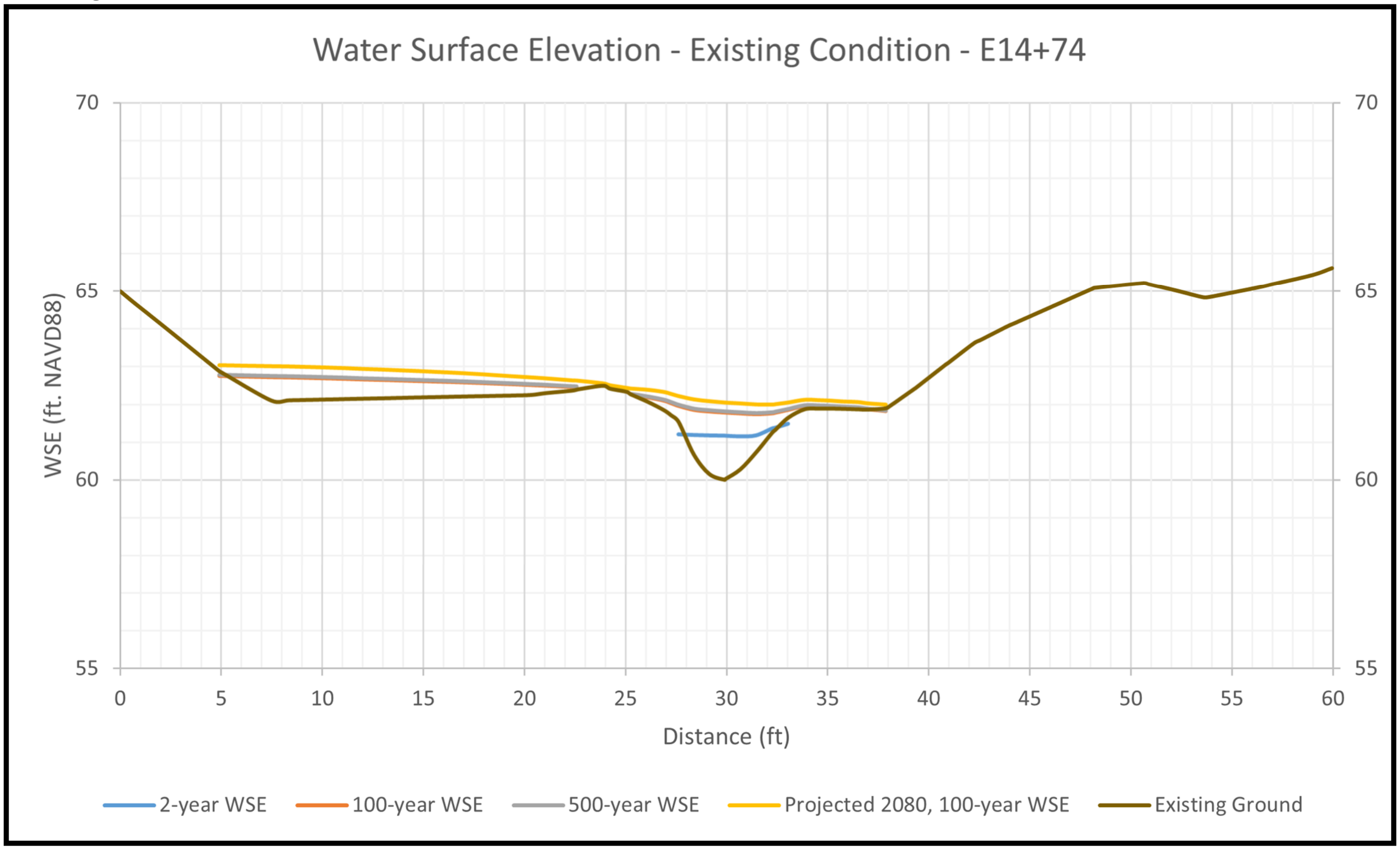
Existing Condition Section — Station E13+40



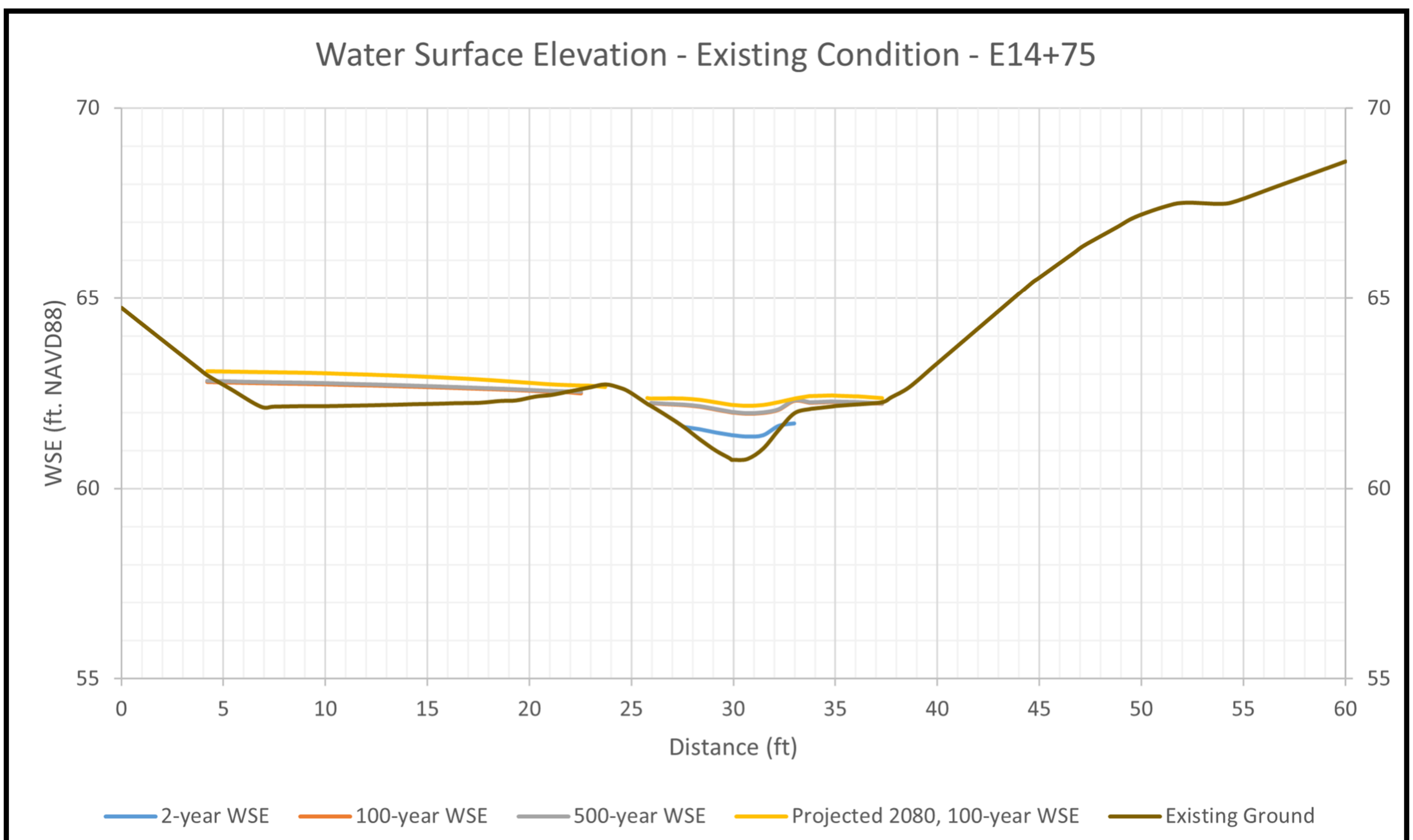
Existing Condition Section — Station E13+75



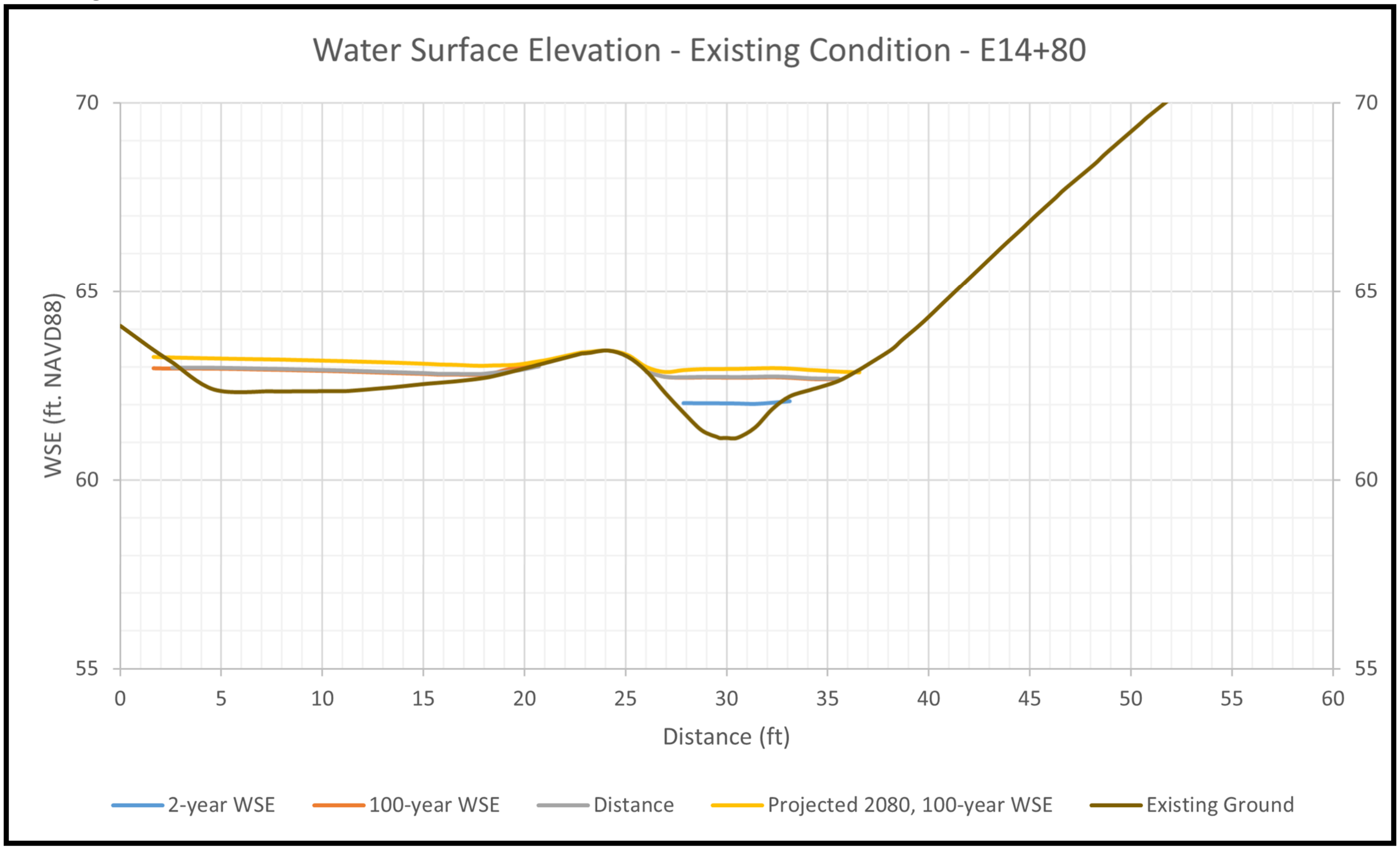
Existing Condition Section — Station E14+74



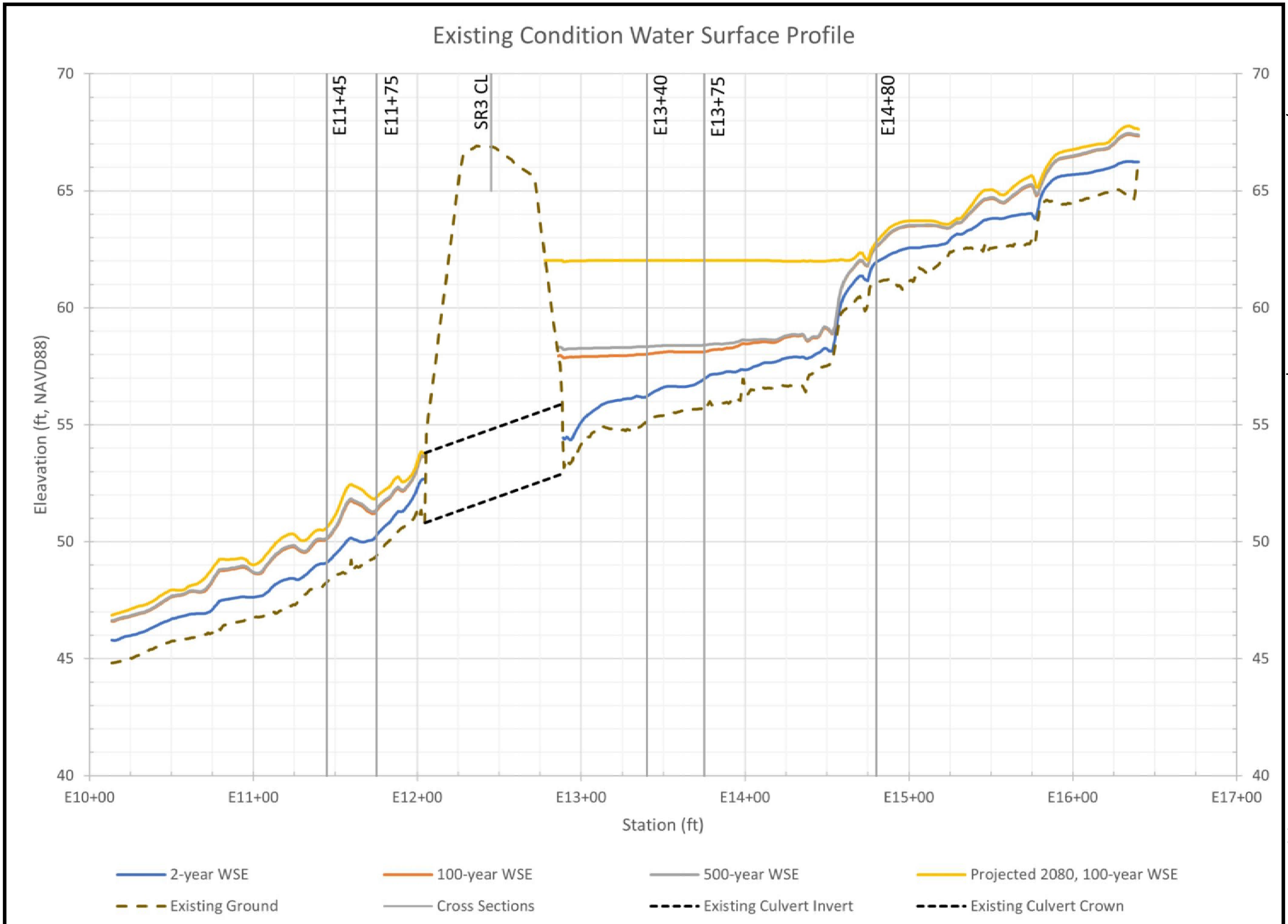
Existing Condition Section — Station E14+75



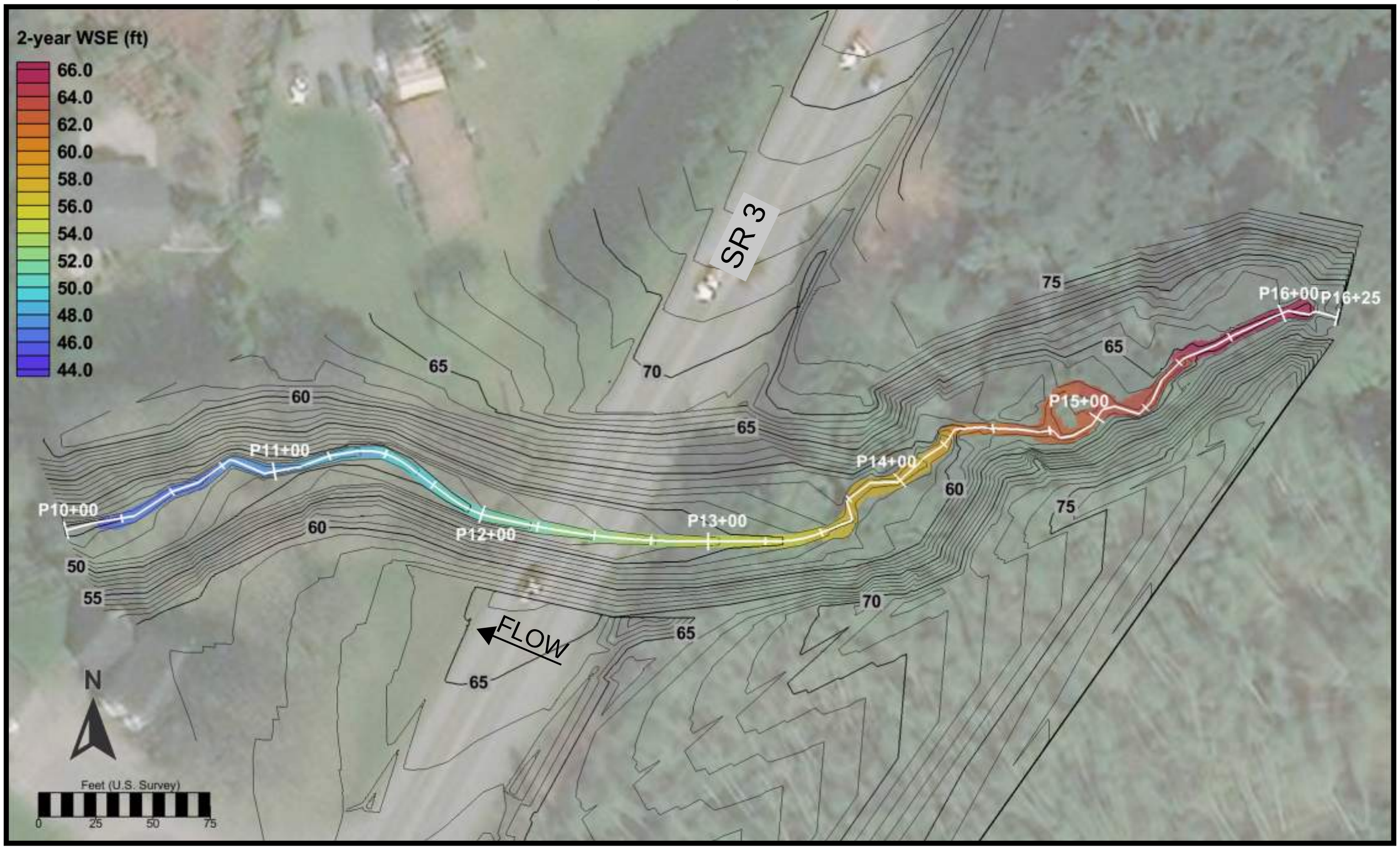
Existing Condition Section — Station E14+80



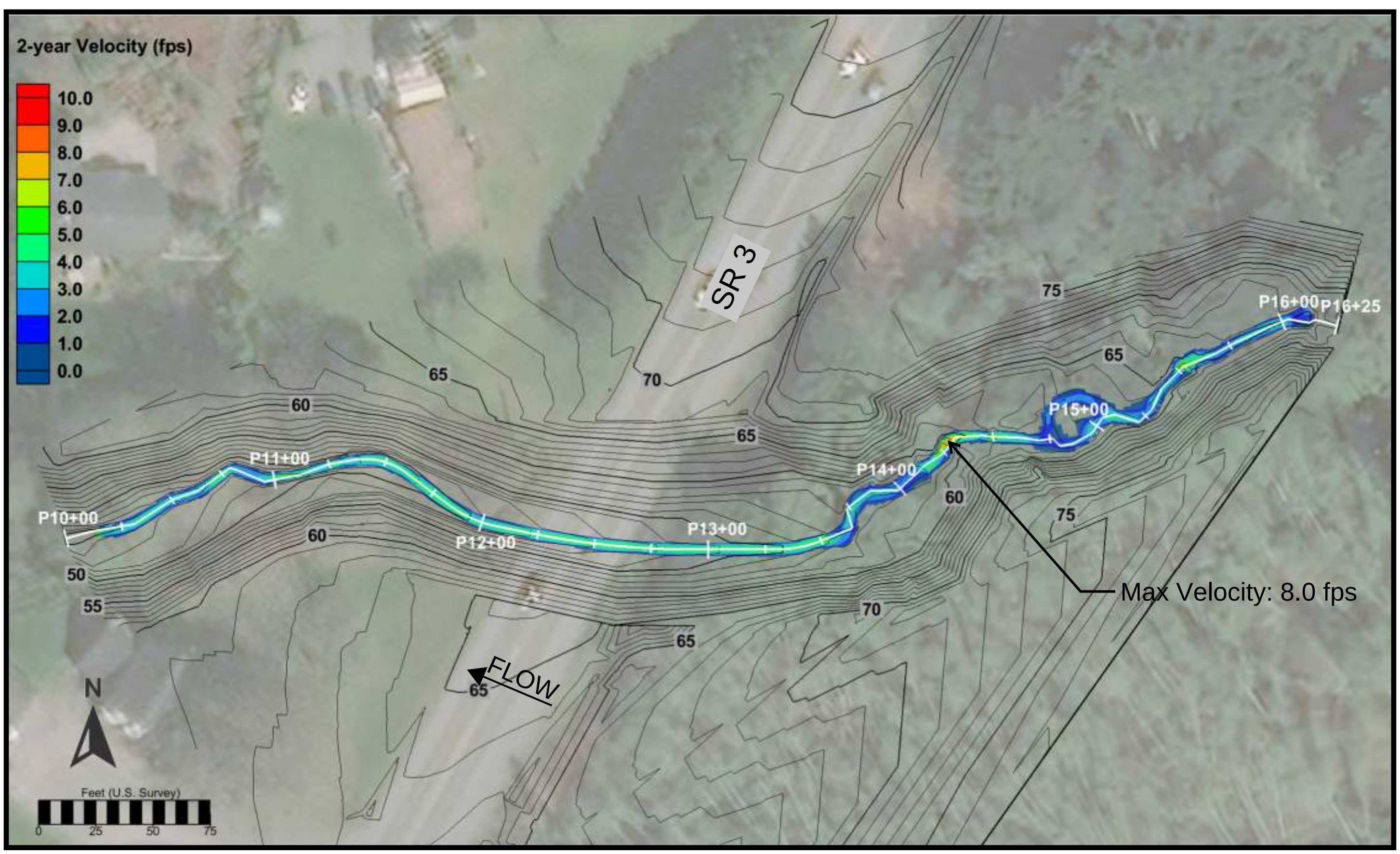
Existing Condition Water Surface Profile (ft, NAVD88)



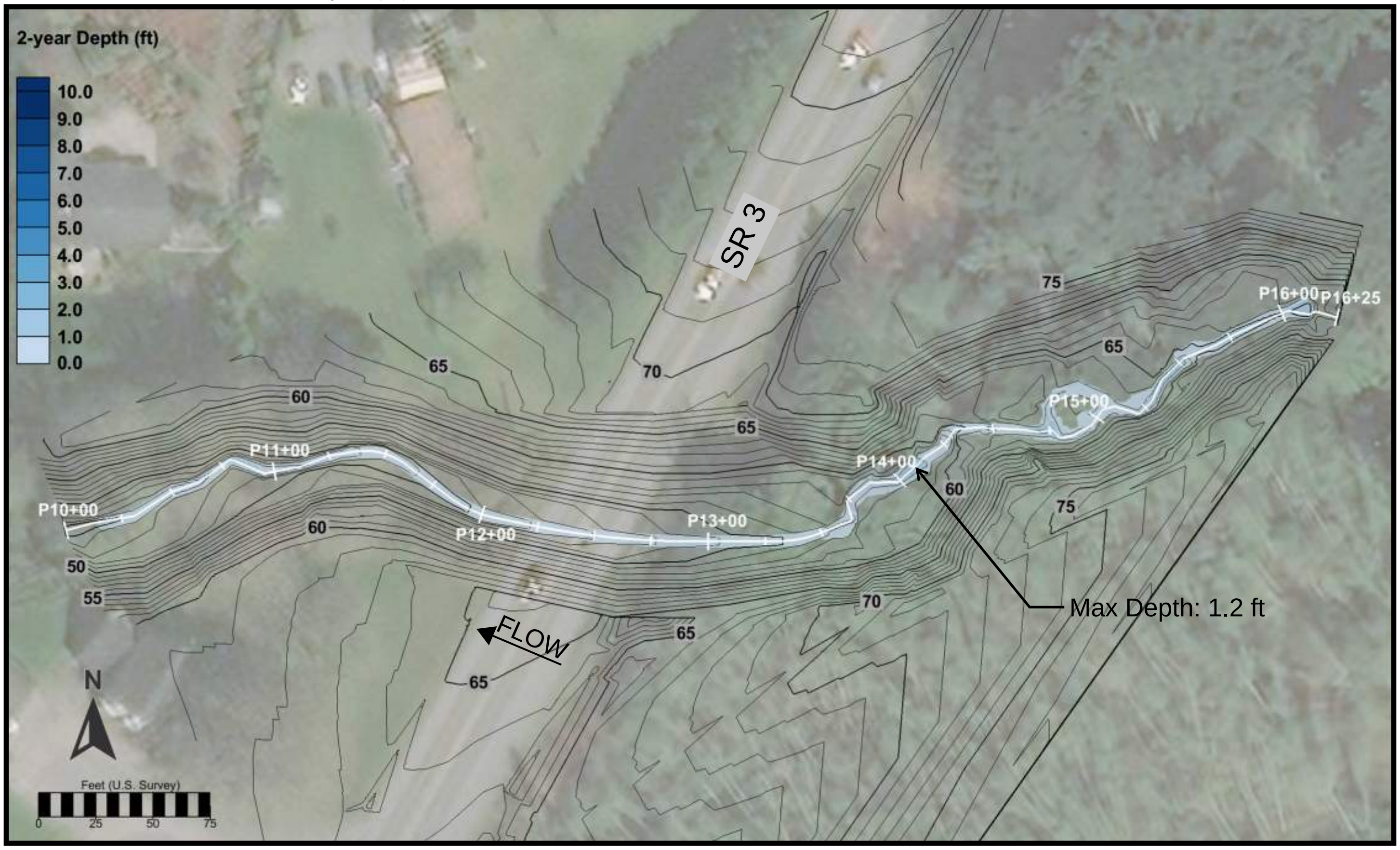
Natural Condition — Q2 Water Surface Elevations (ft, NAVD 88)



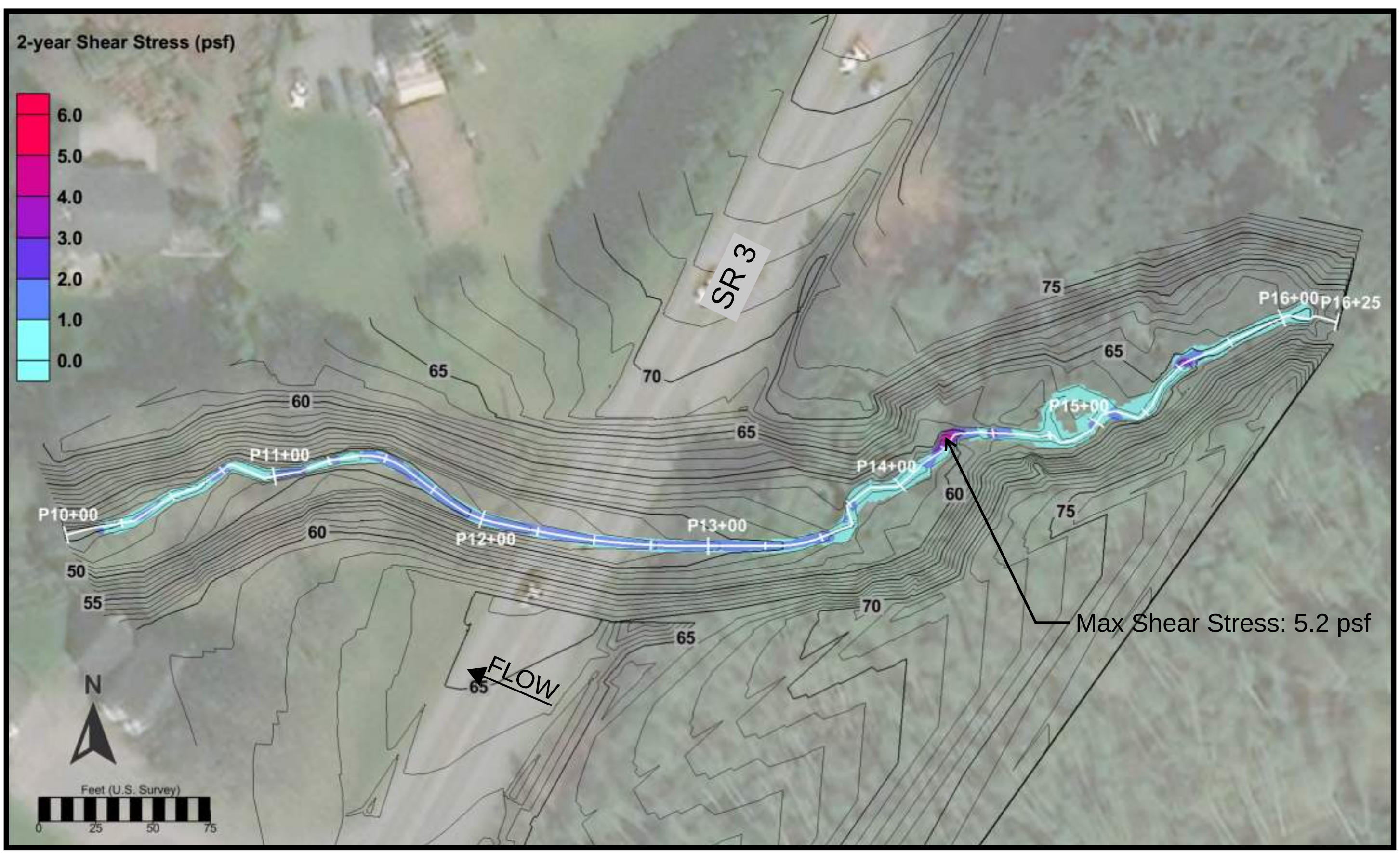
Natural Condition—Q2 Velocity (fps)



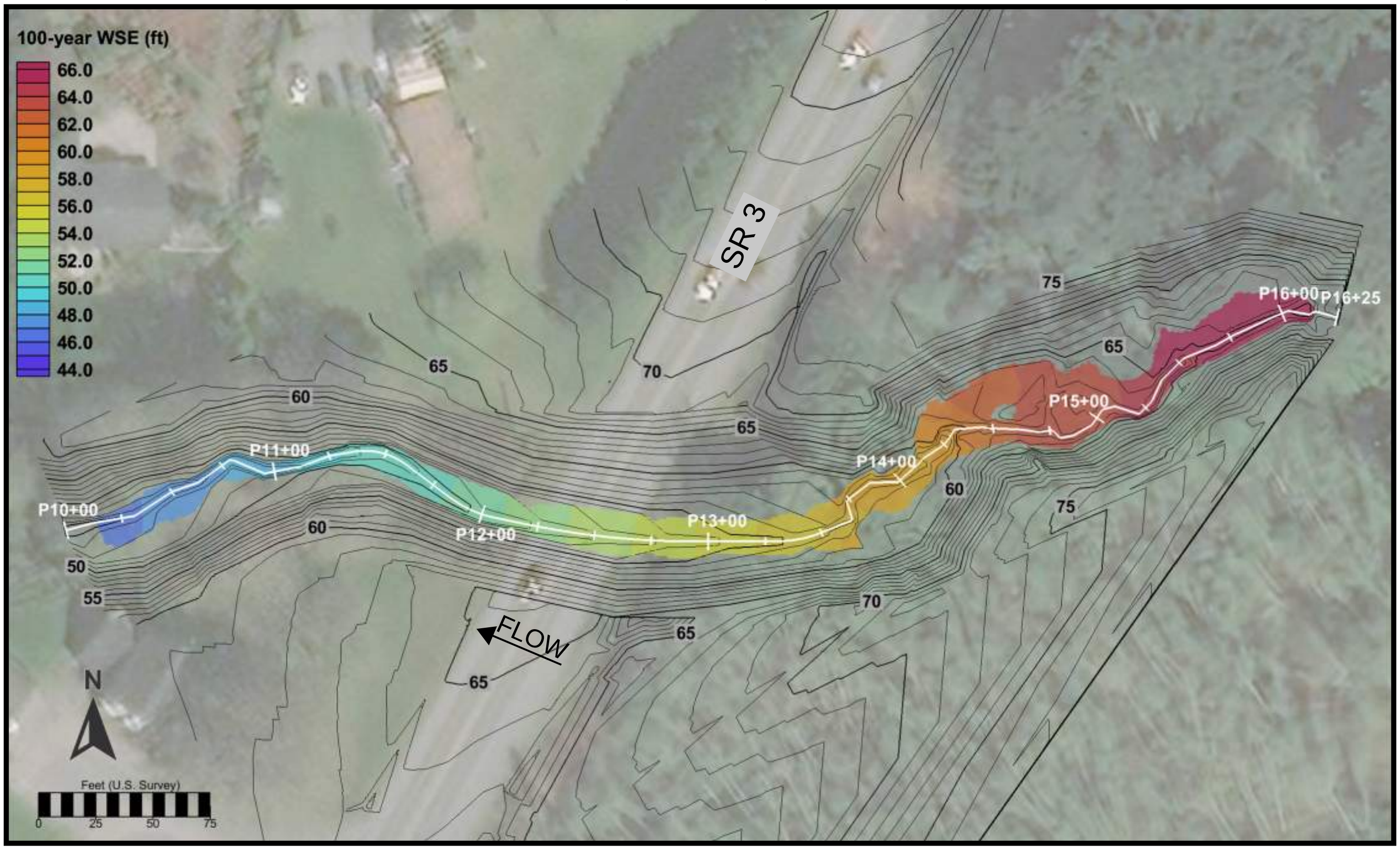
Natural Condition — Q2 Depth (ft)



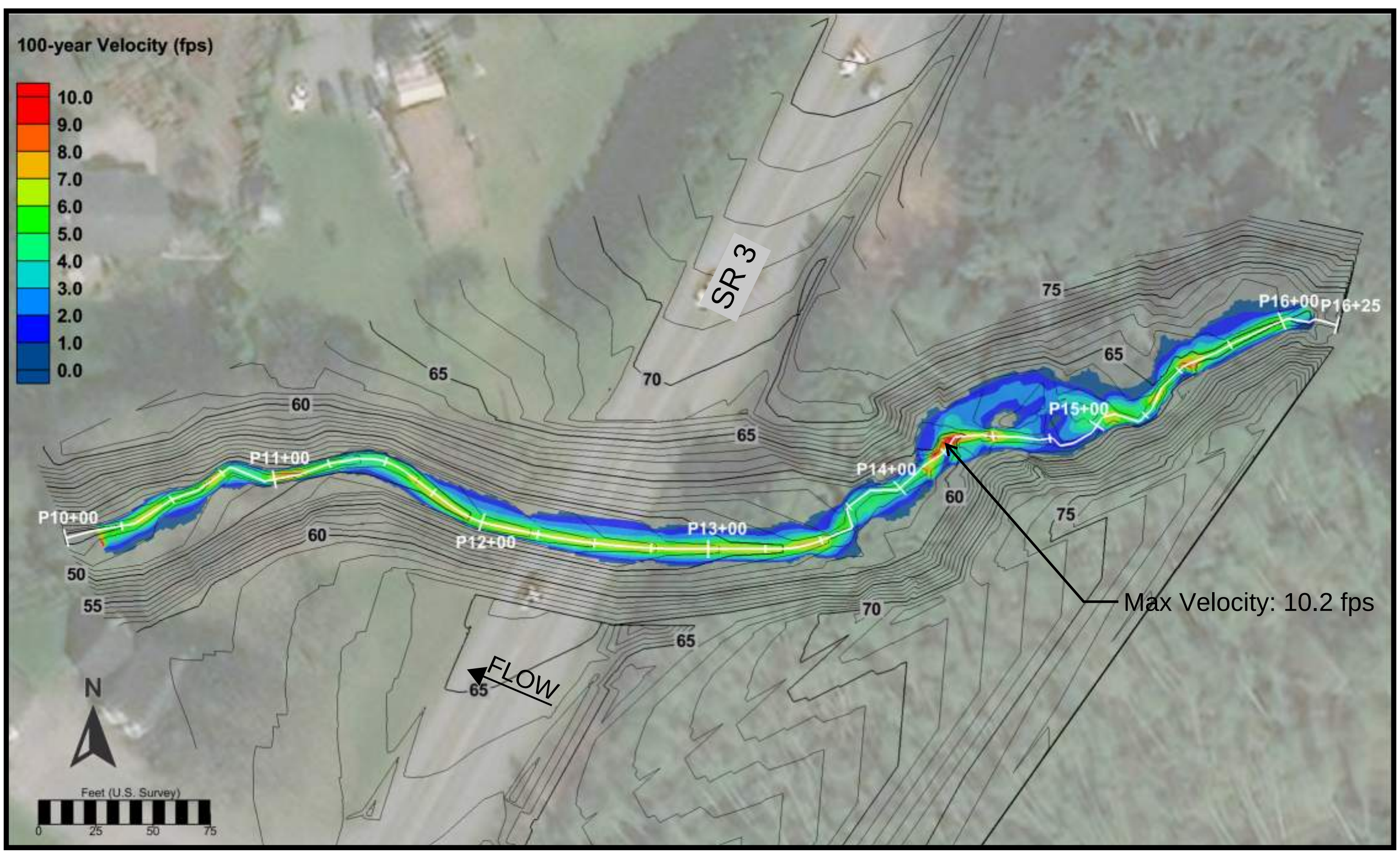
Natural Condition—Q2 Shear Stress (psf)



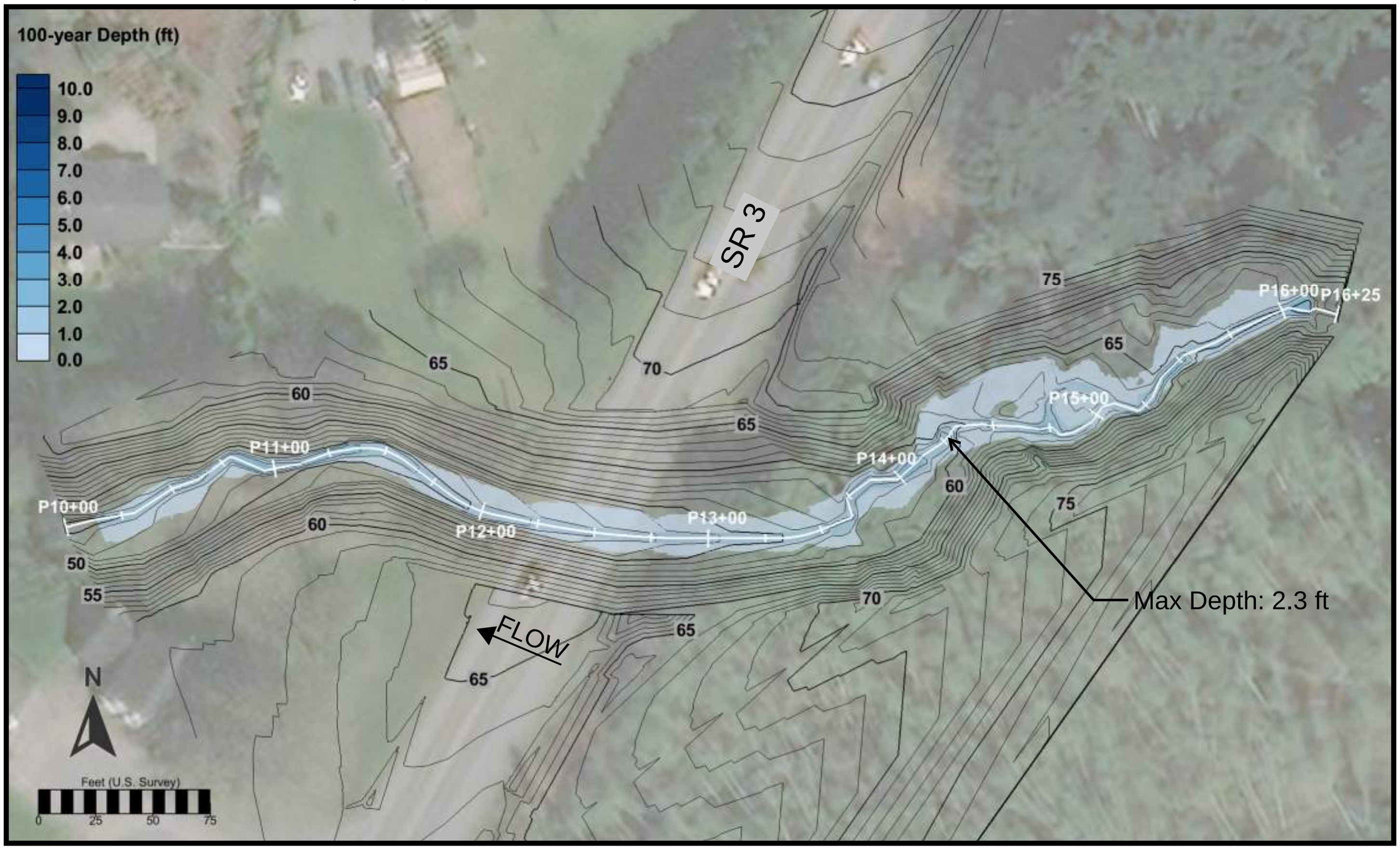
Natural Condition — Q100 Water Surface Elevations (ft, NAVD 88)



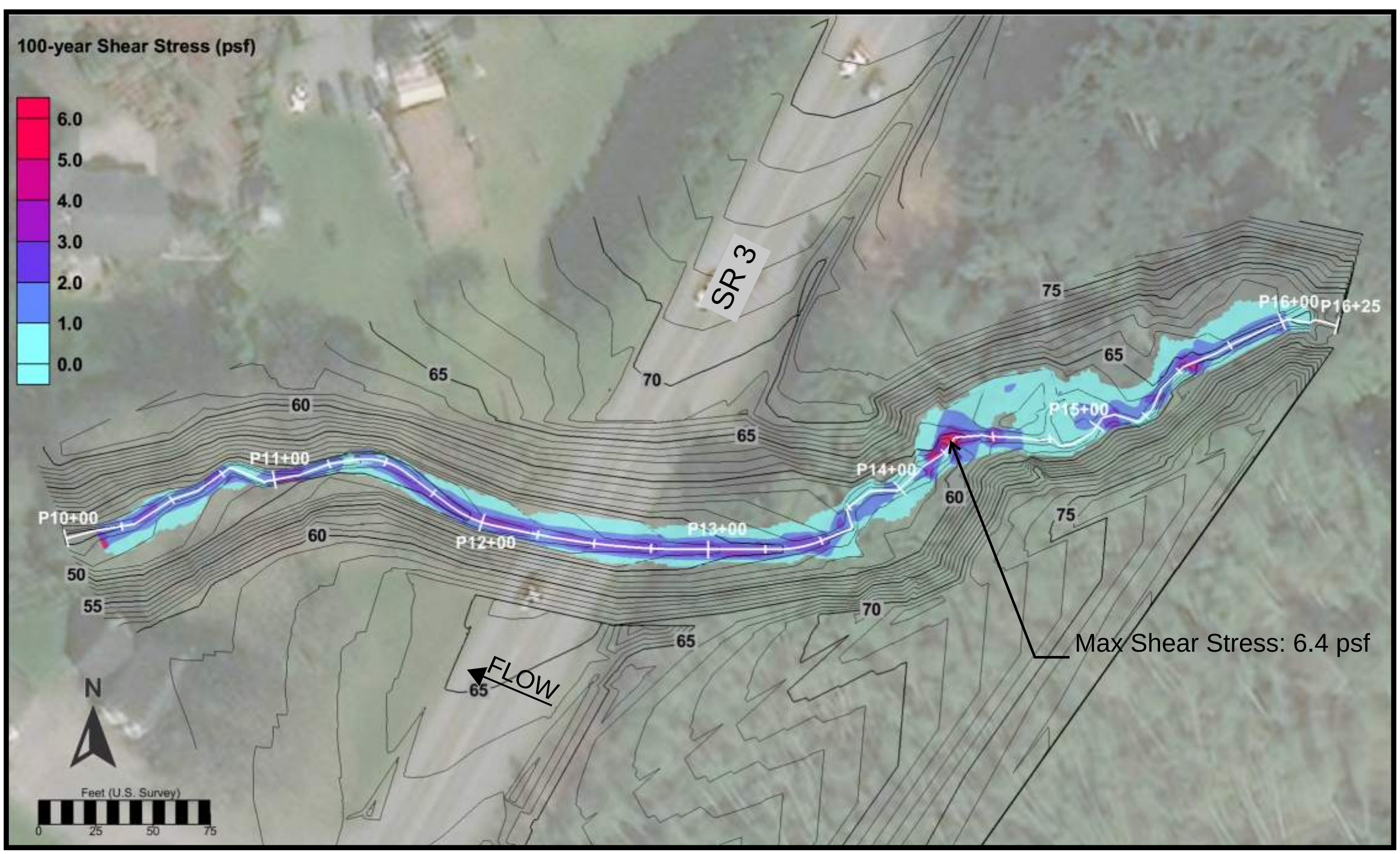
Natural Condition — Q100 Velocity (fps)



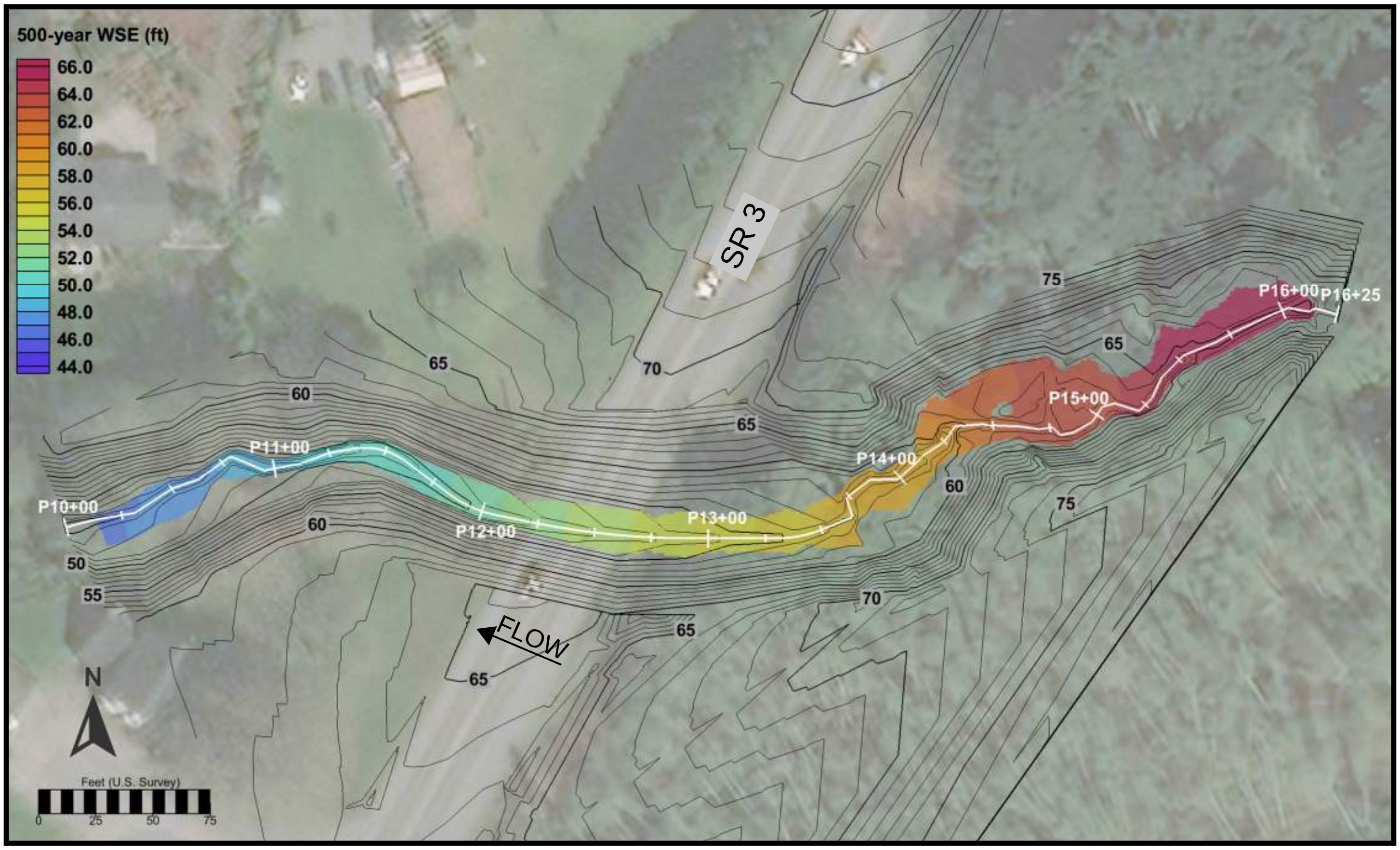
Natural Condition— Q100 Depth (ft)



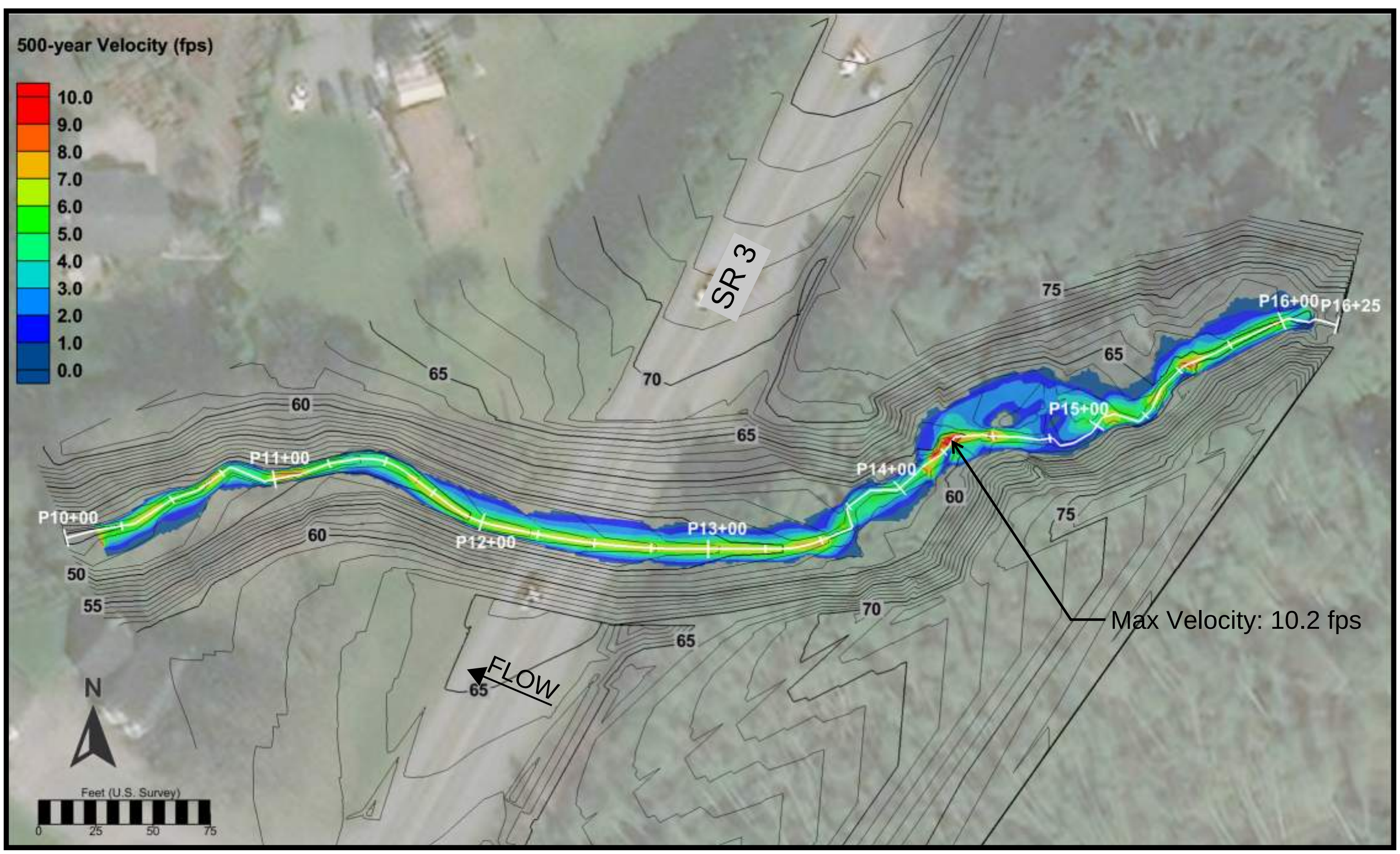
Natural Condition— Q100 Shear Stress (psf)



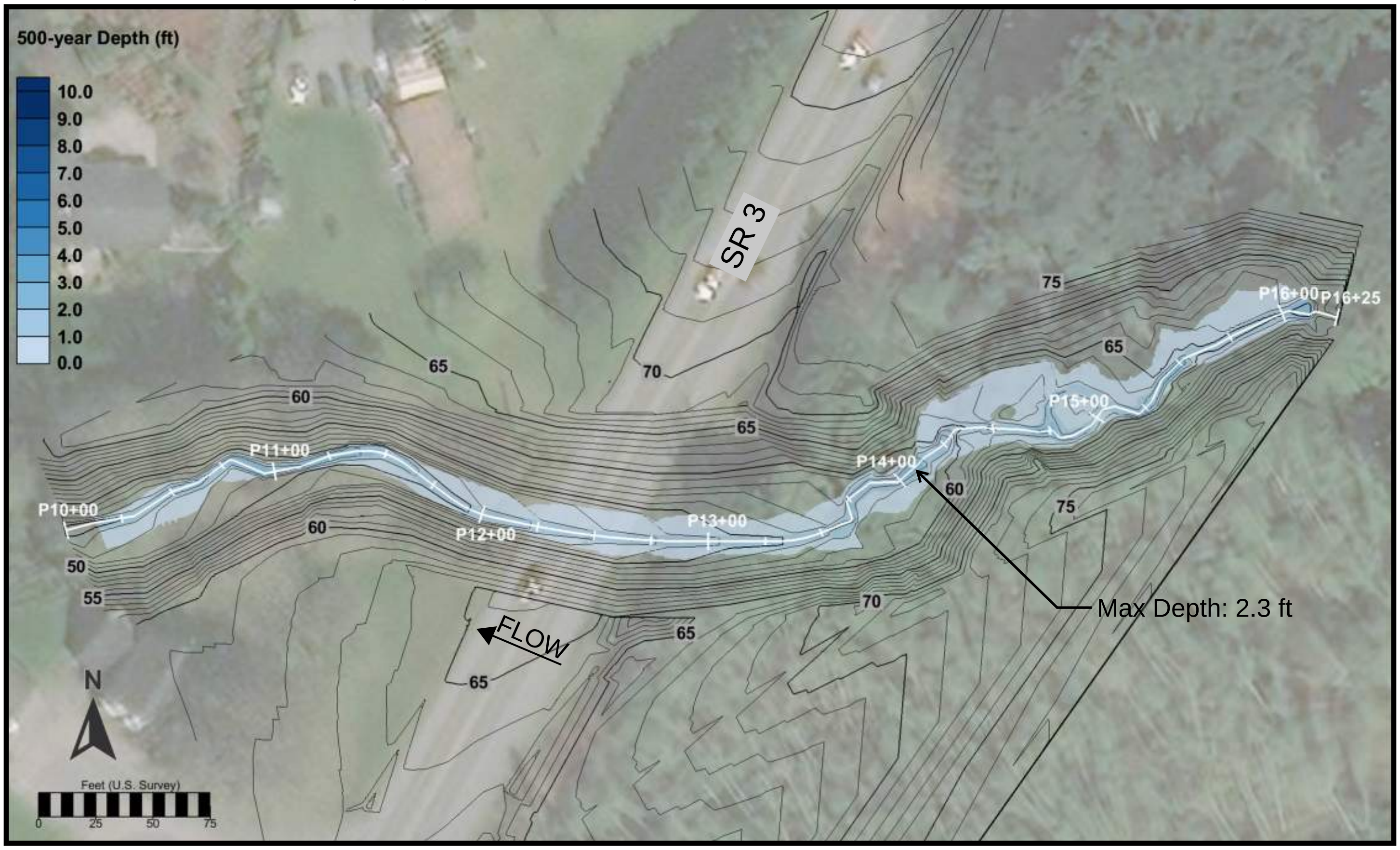
Natural Condition — Q500 Water Surface Elevations (ft, NAVD 88)



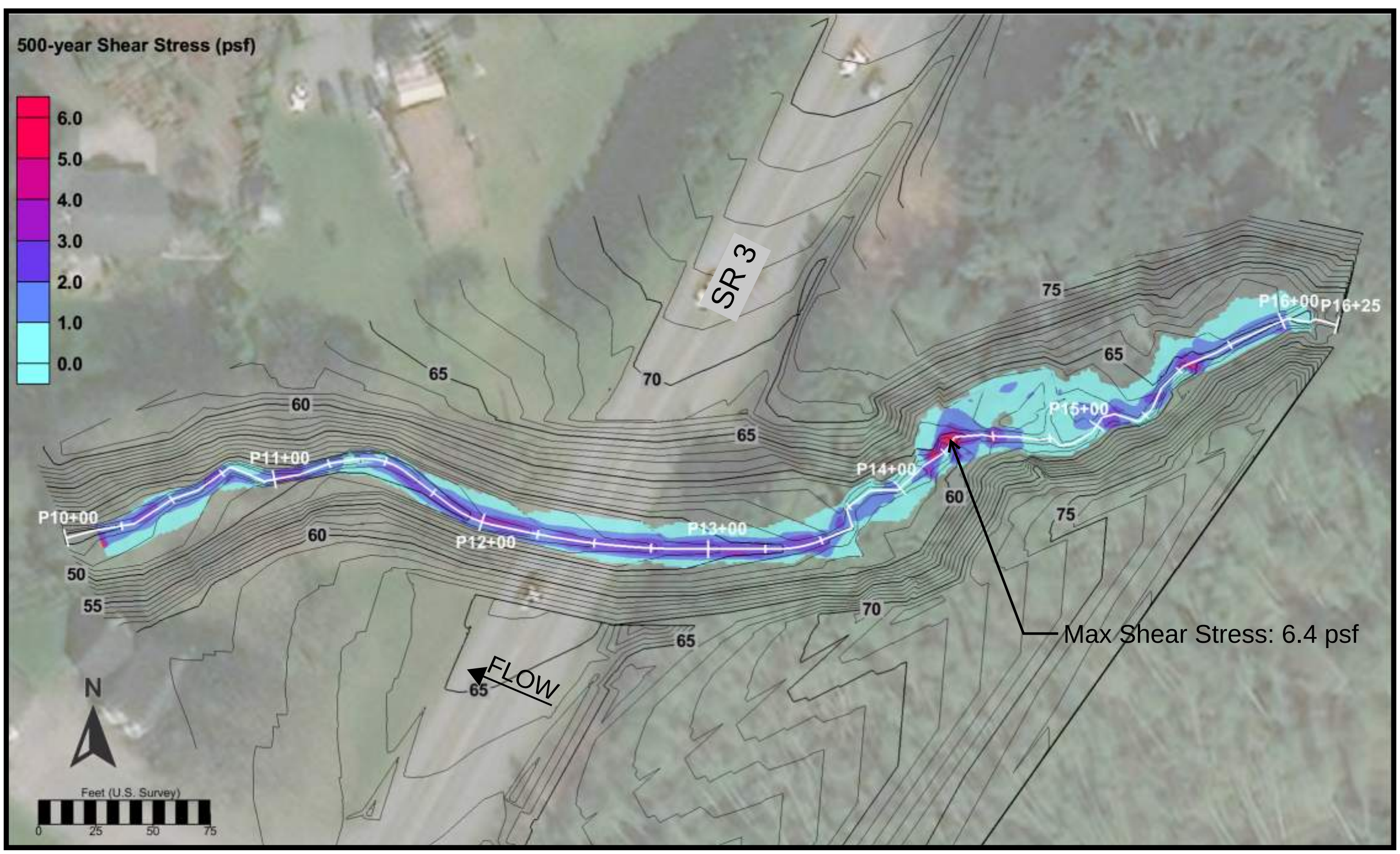
Natural Condition — Q500 Velocity (fps)



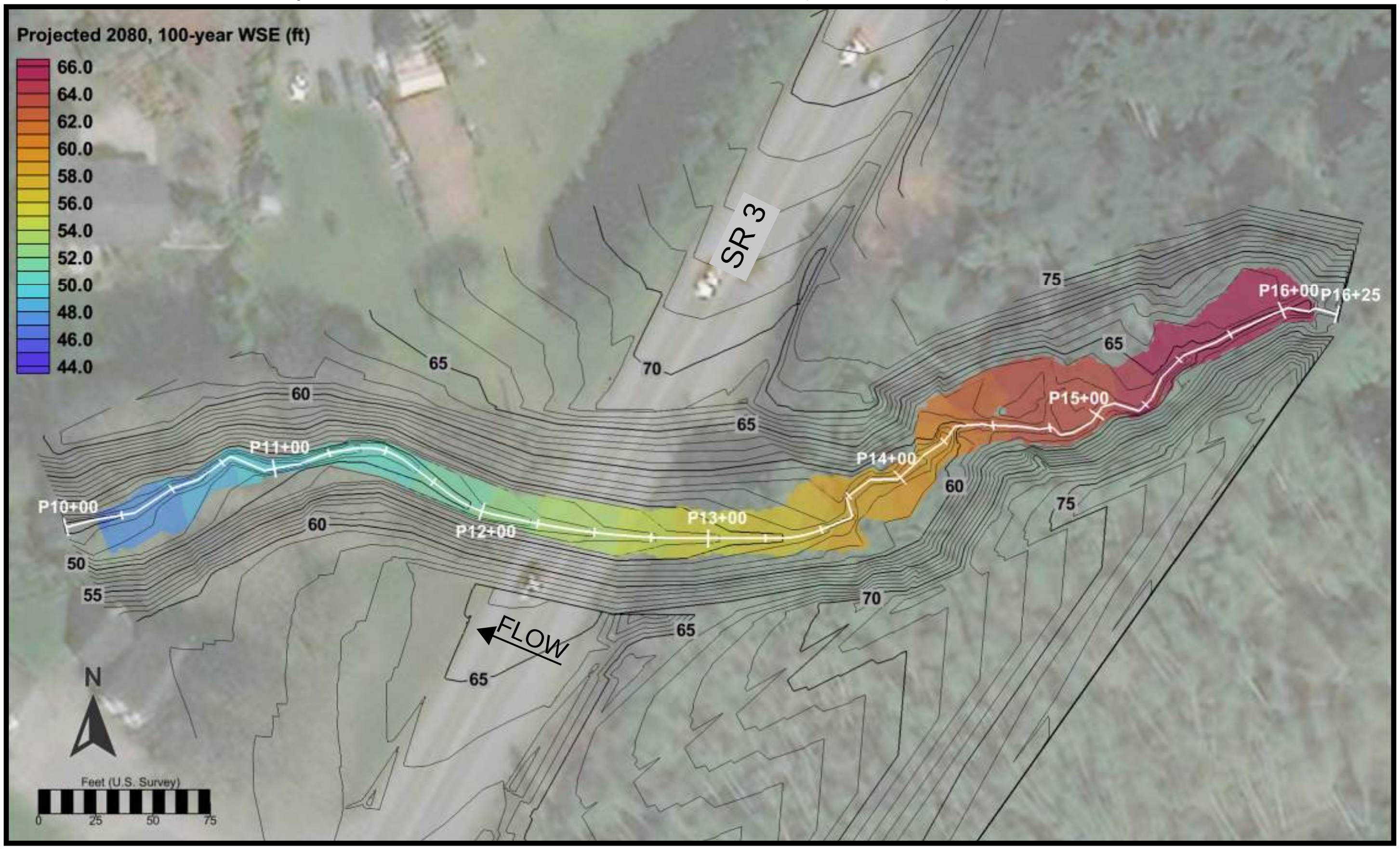
Natural Condition— Q500 Depth (ft)



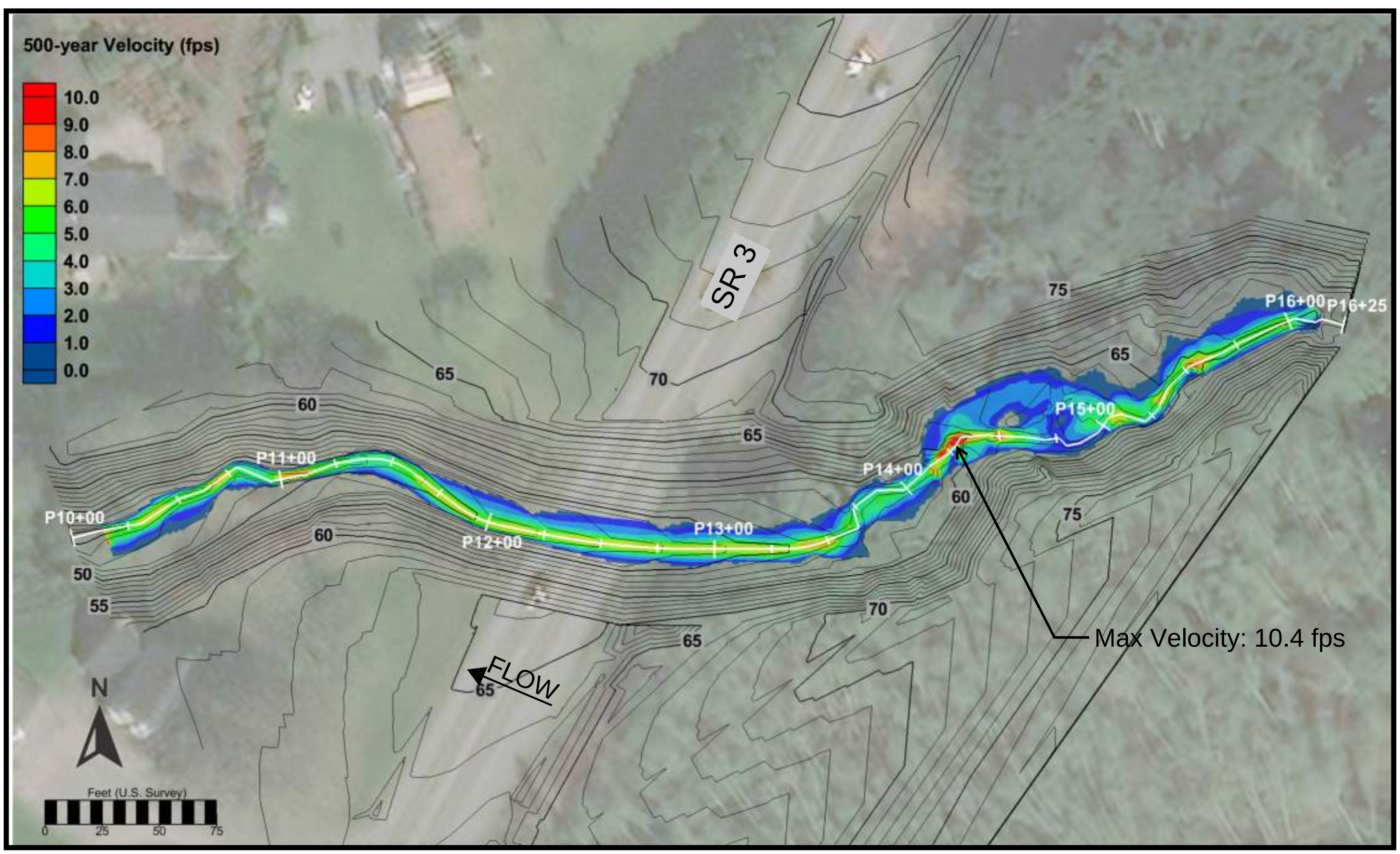
Natural Condition— Q500 Shear Stress (psf)



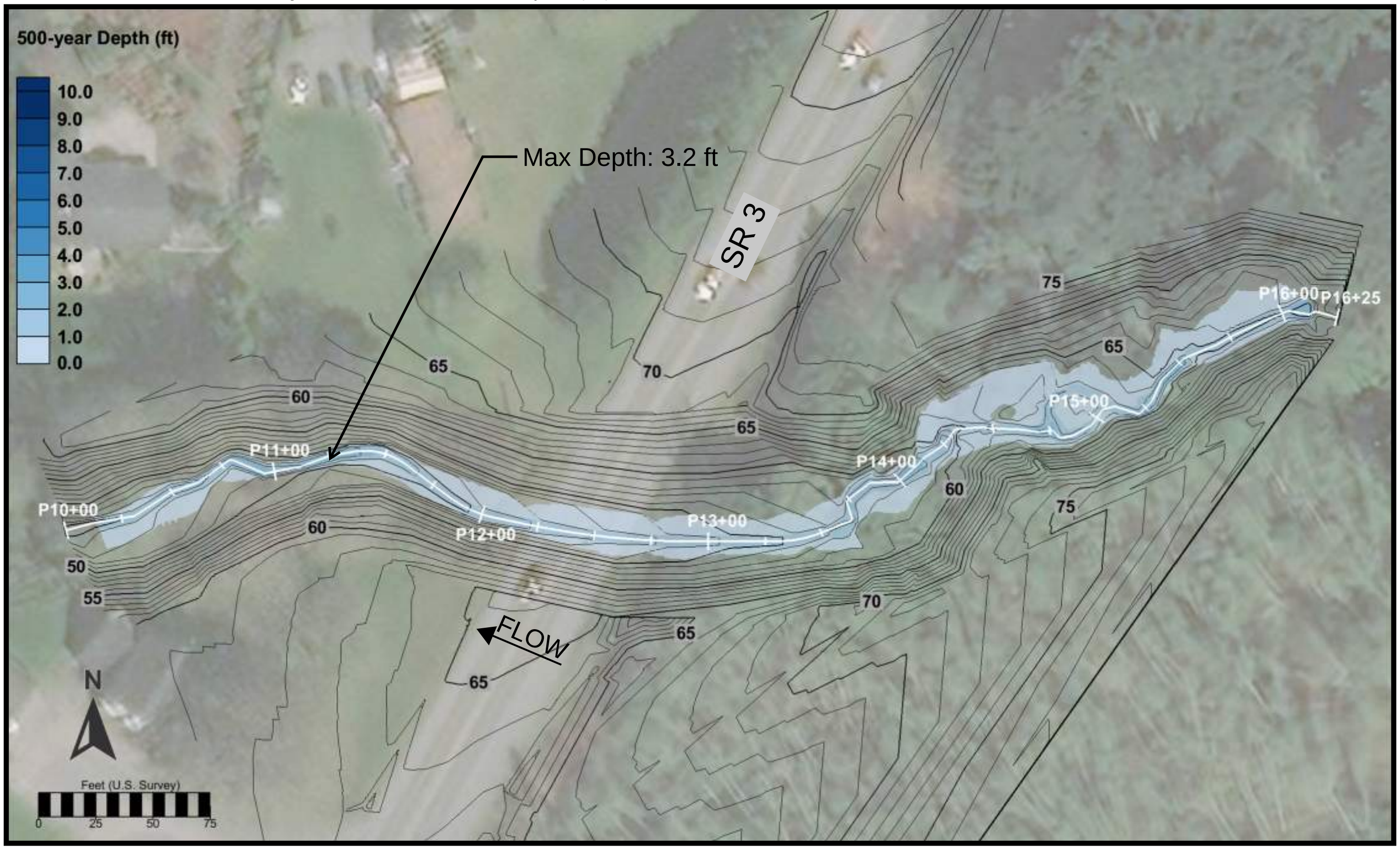
Natural Condition — Projected 2080 Q100 Water Surface Elevations (ft, NAVD 88)



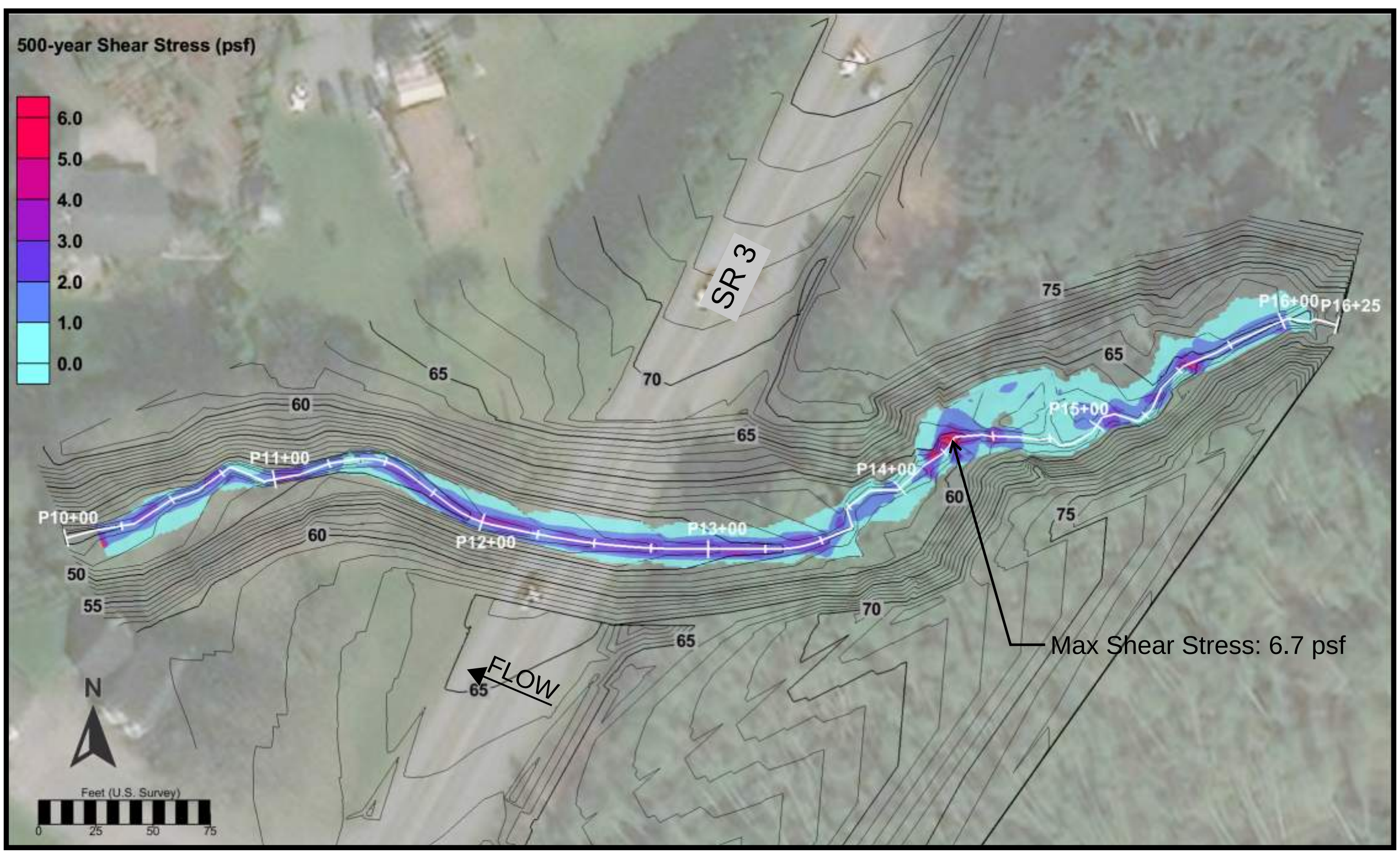
Natural Condition — Projected 2080 Q100 Velocity (fps)



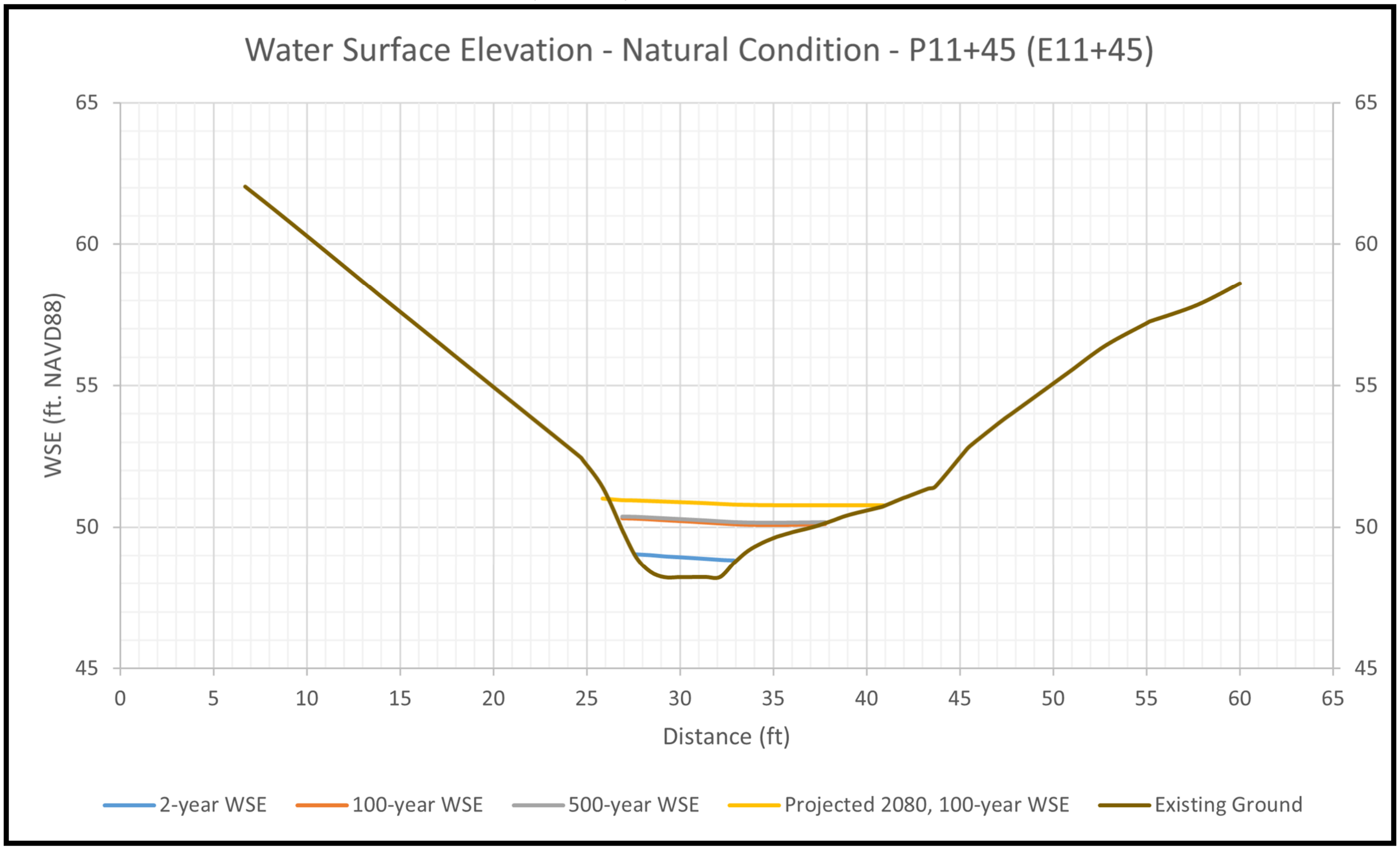
Natural Condition— Projected 2080 Q100 Depth (ft)



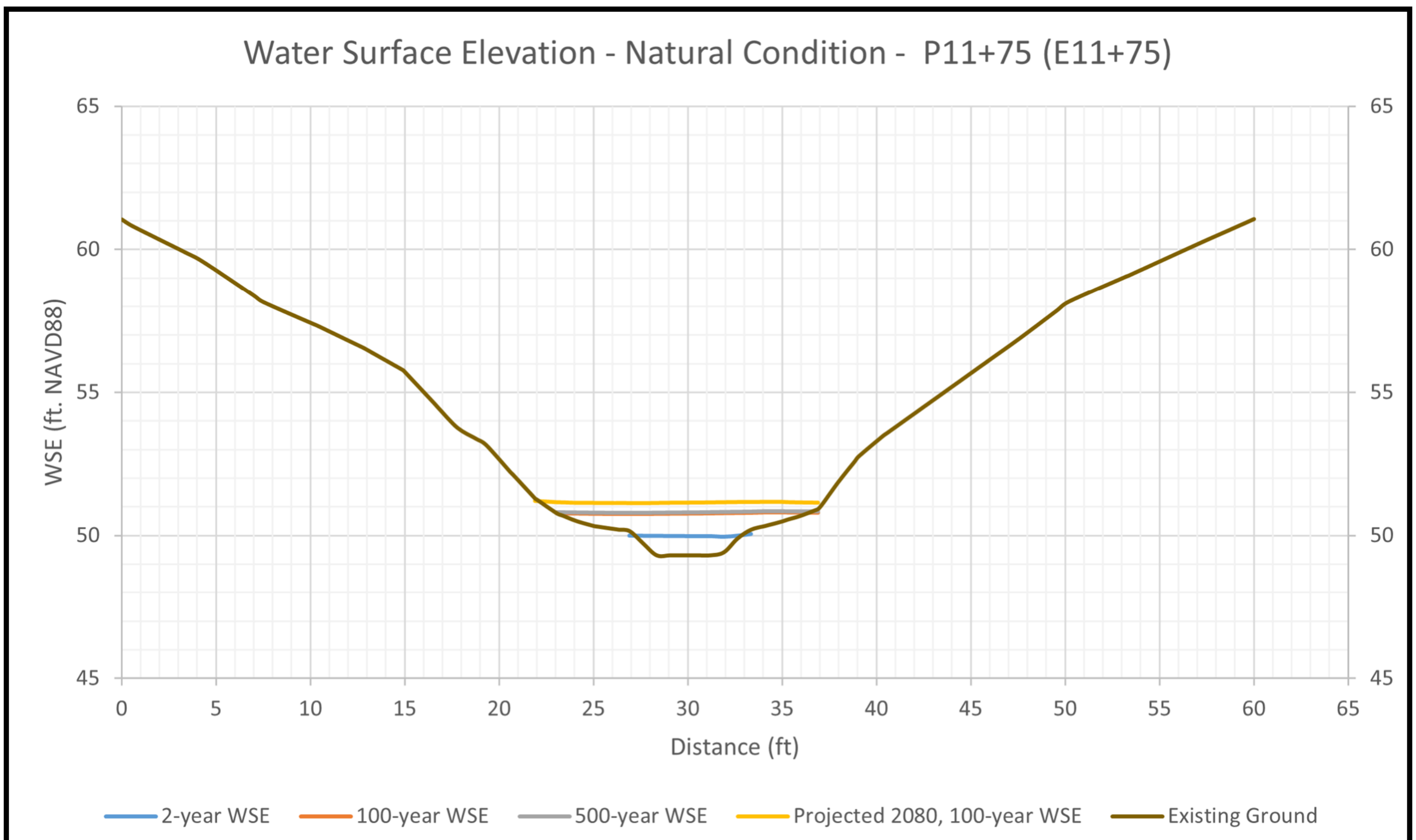
Natural Condition— Projected 2080 Q100 Shear Stress (psf)



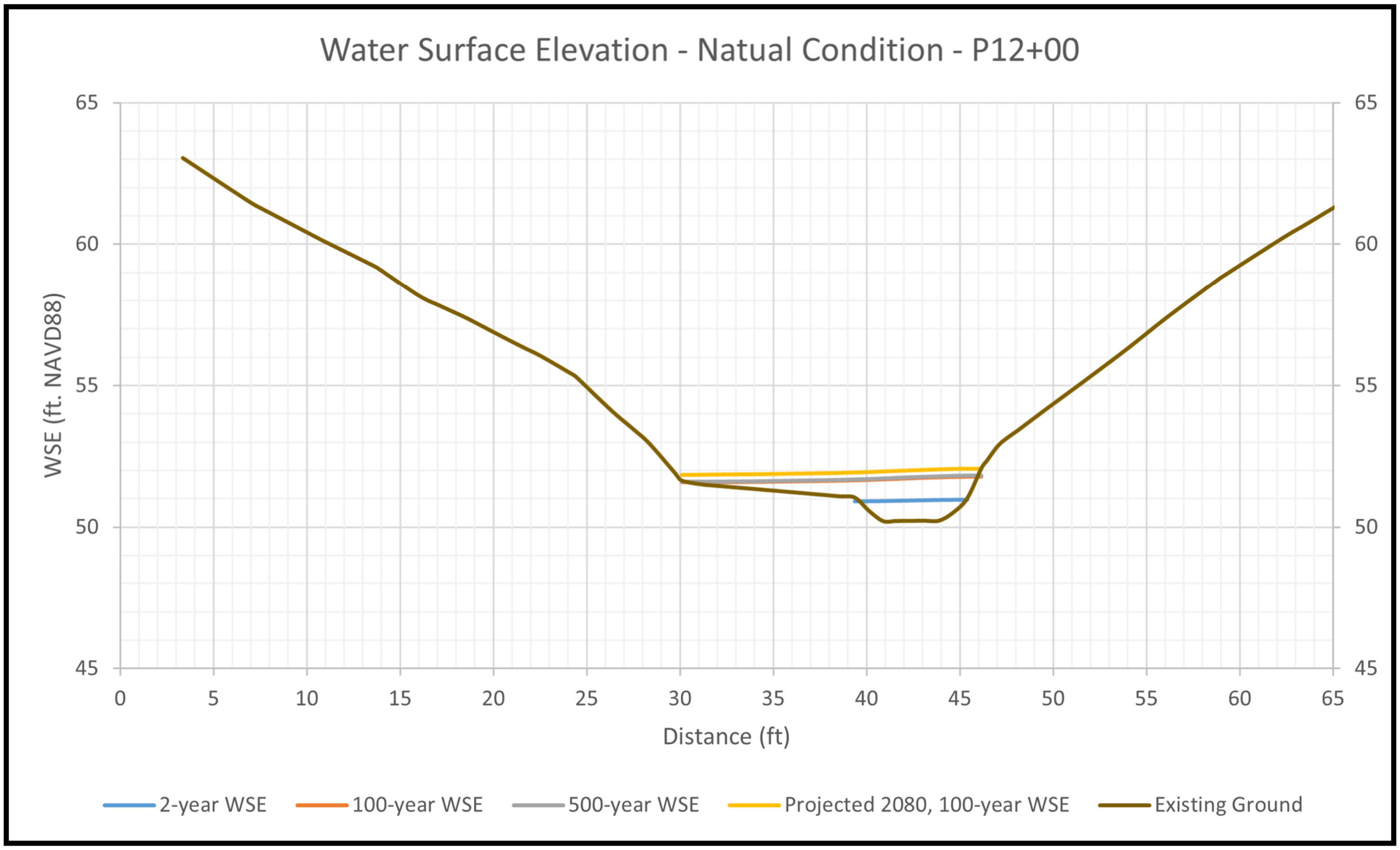
Natural Condition Section — Station P11+45 (E11+45)



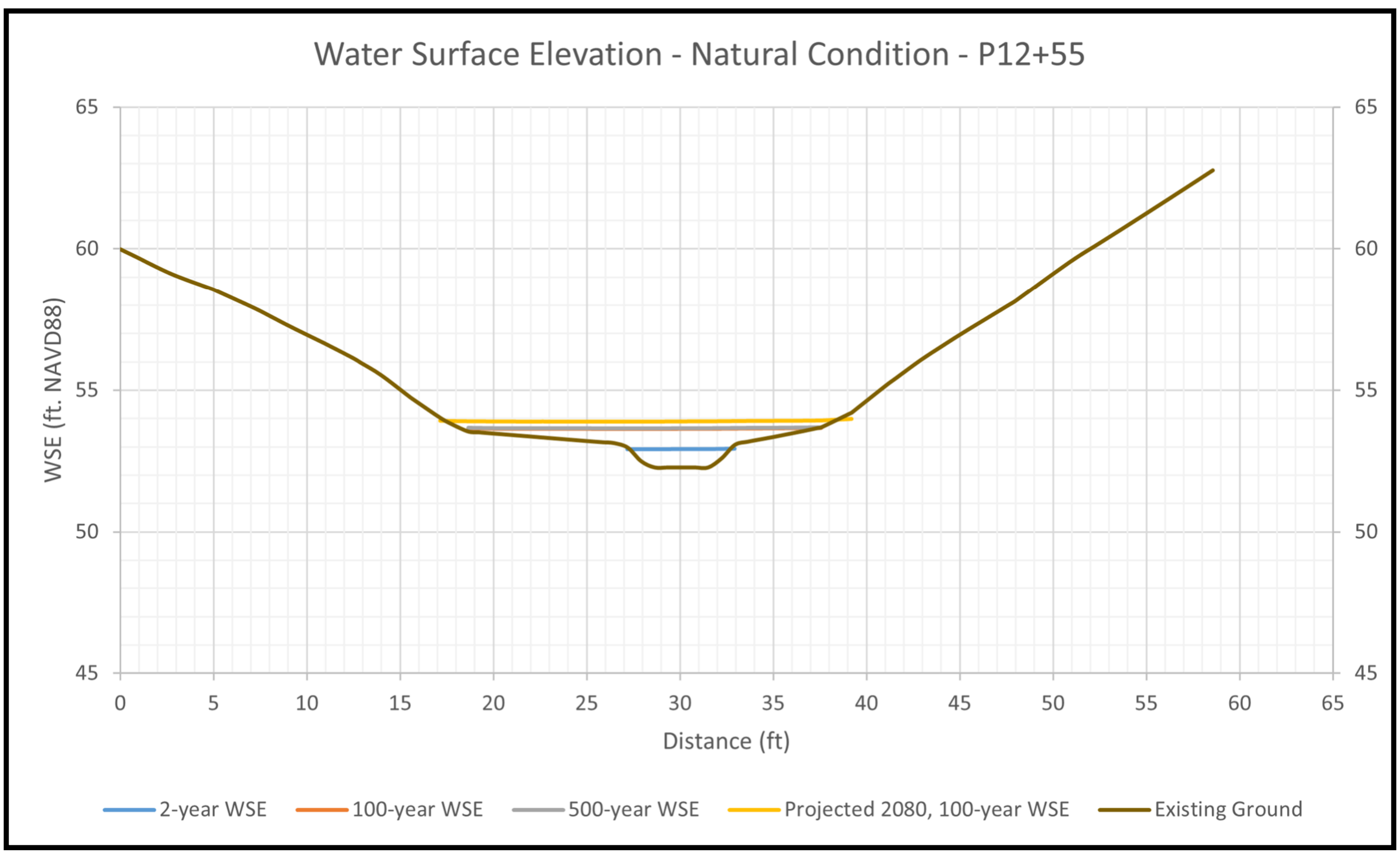
Natural Condition Section — Station P11+75 (E11+75)



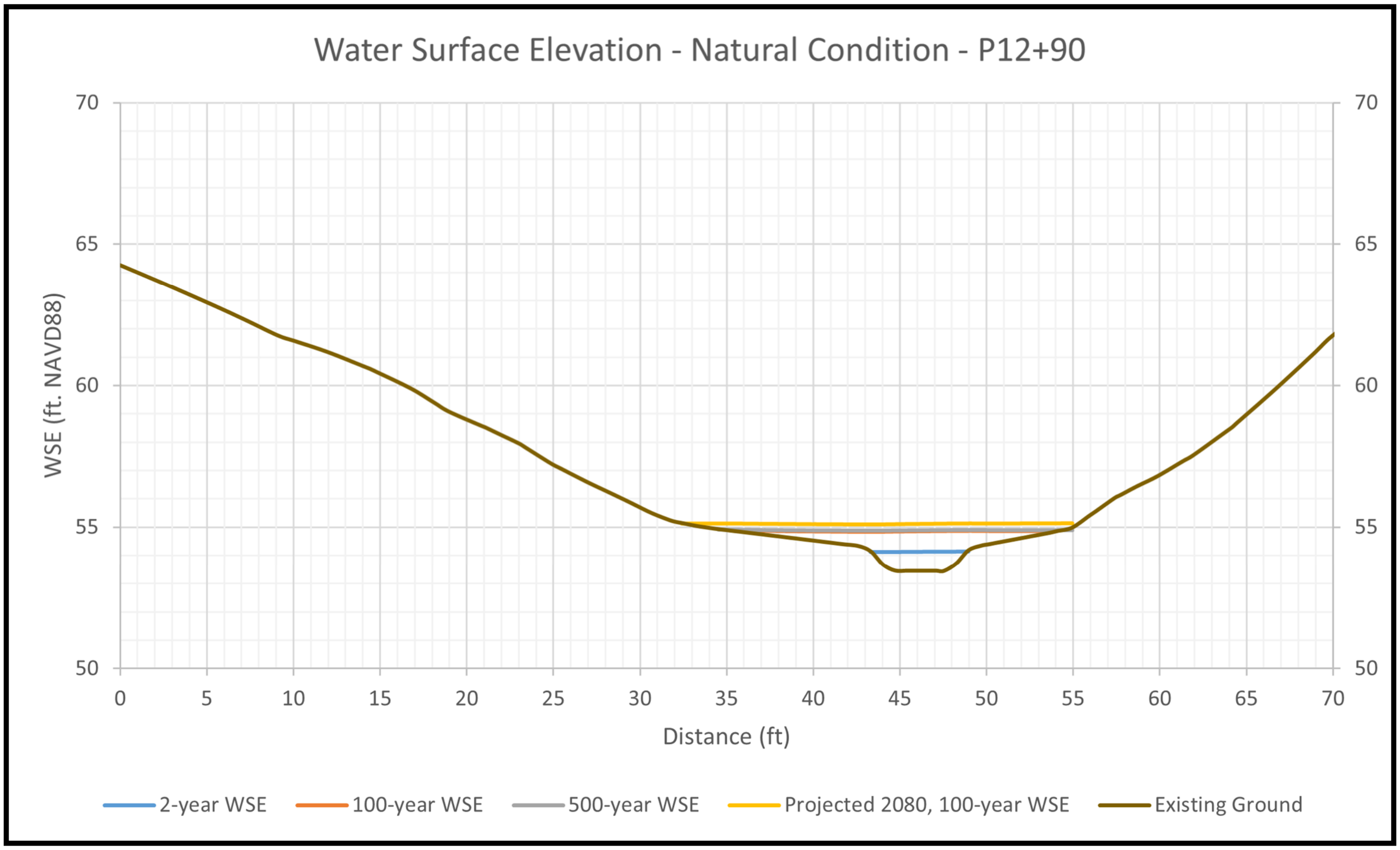
Natural Condition Section — Station P12+00



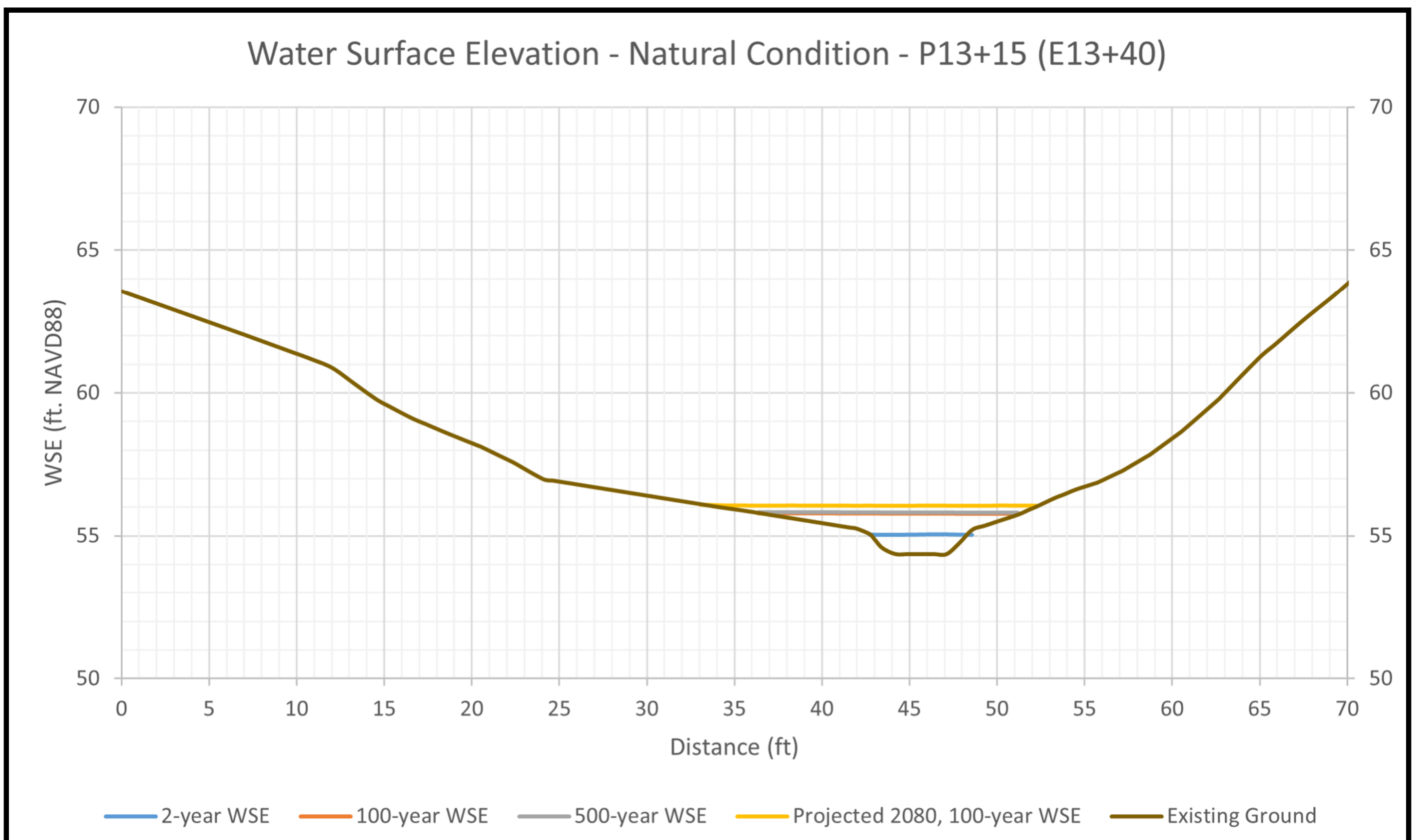
Natural Condition Section — Station P12+55



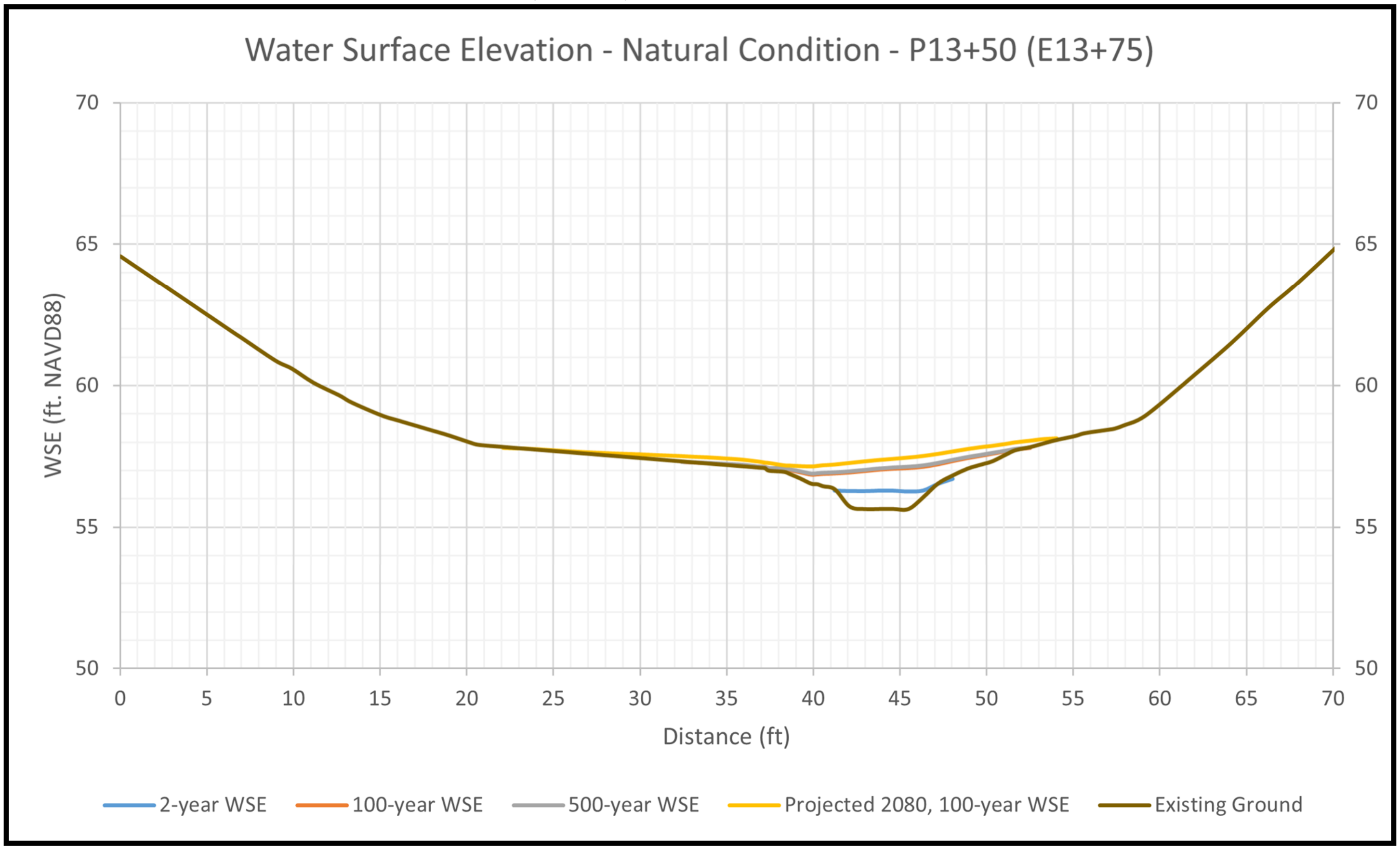
Natural Condition Section — Station P12+90



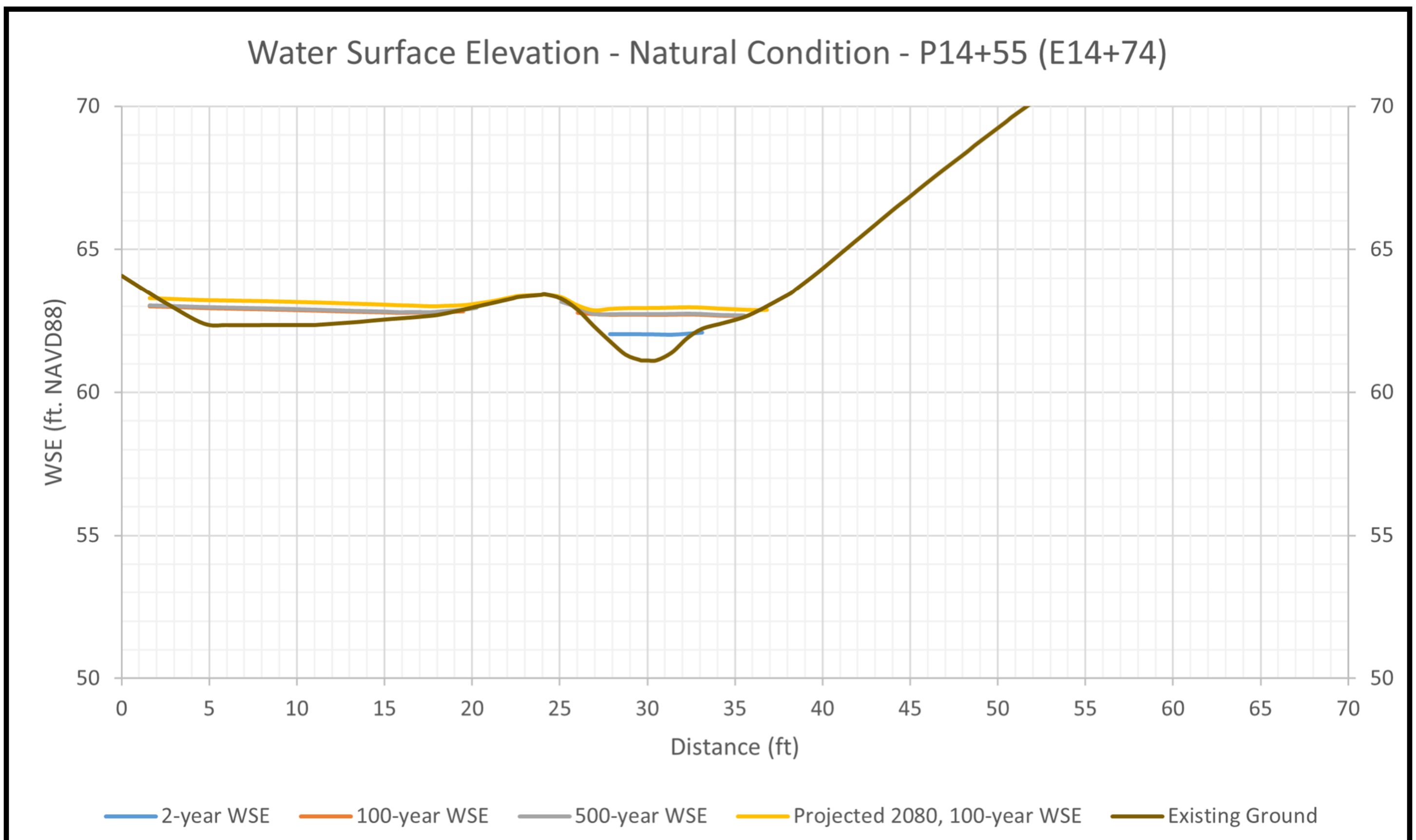
Natural Condition Section — Station P13+15(E13+40)



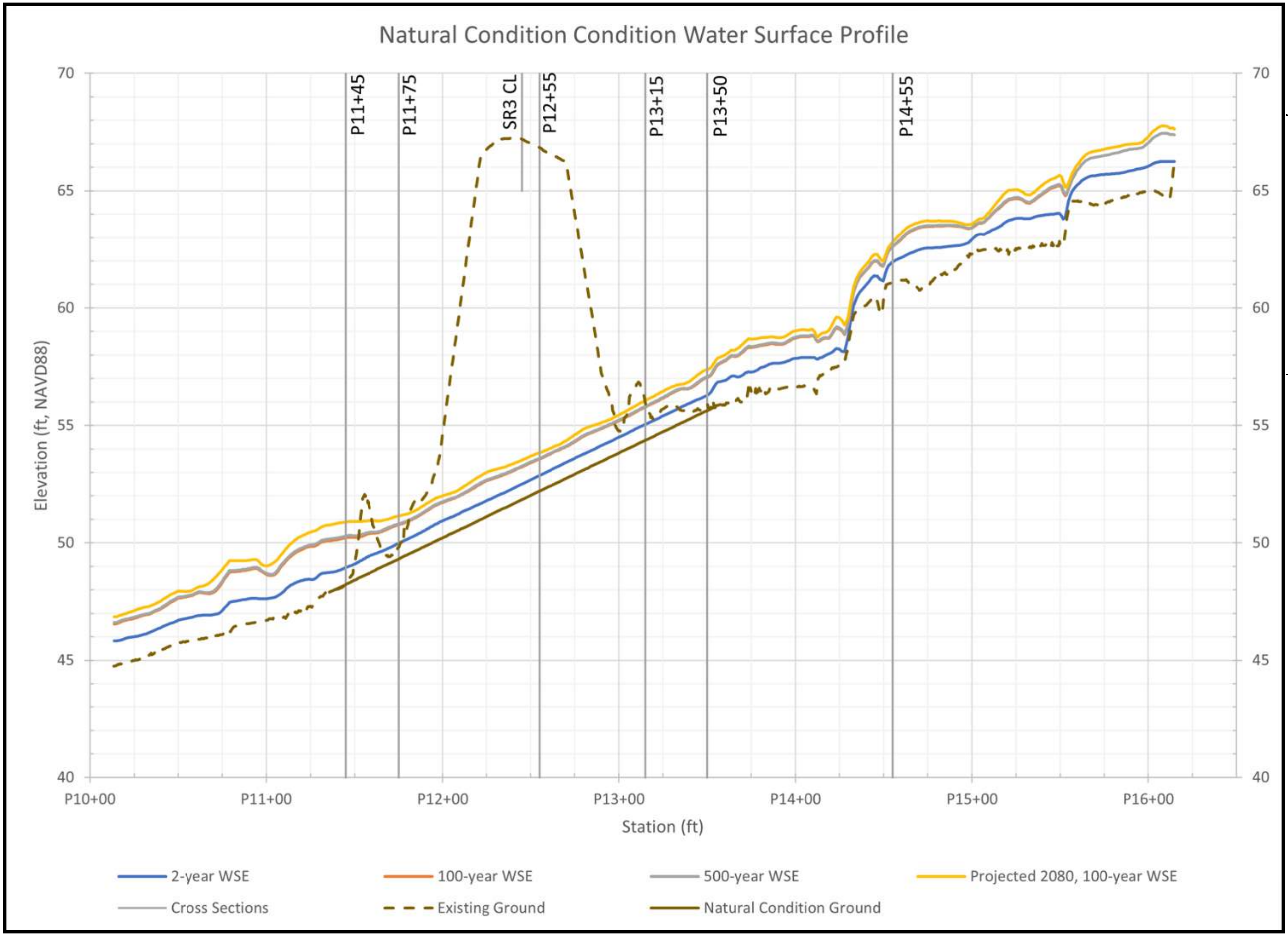
Natural Condition Section — Station P13+50 (E13+75)



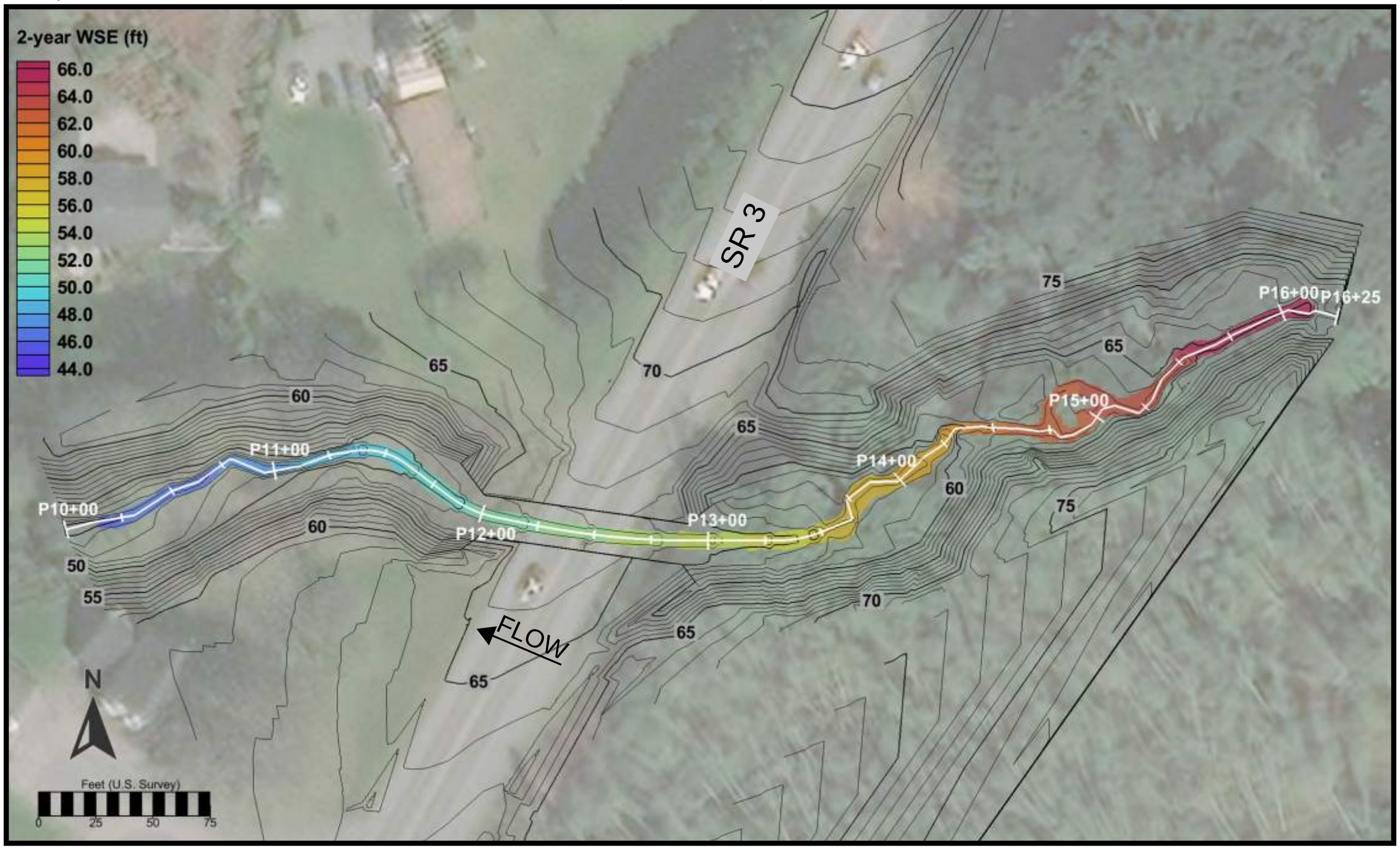
Natural Condition Section — Station P14+55 (E14+74)



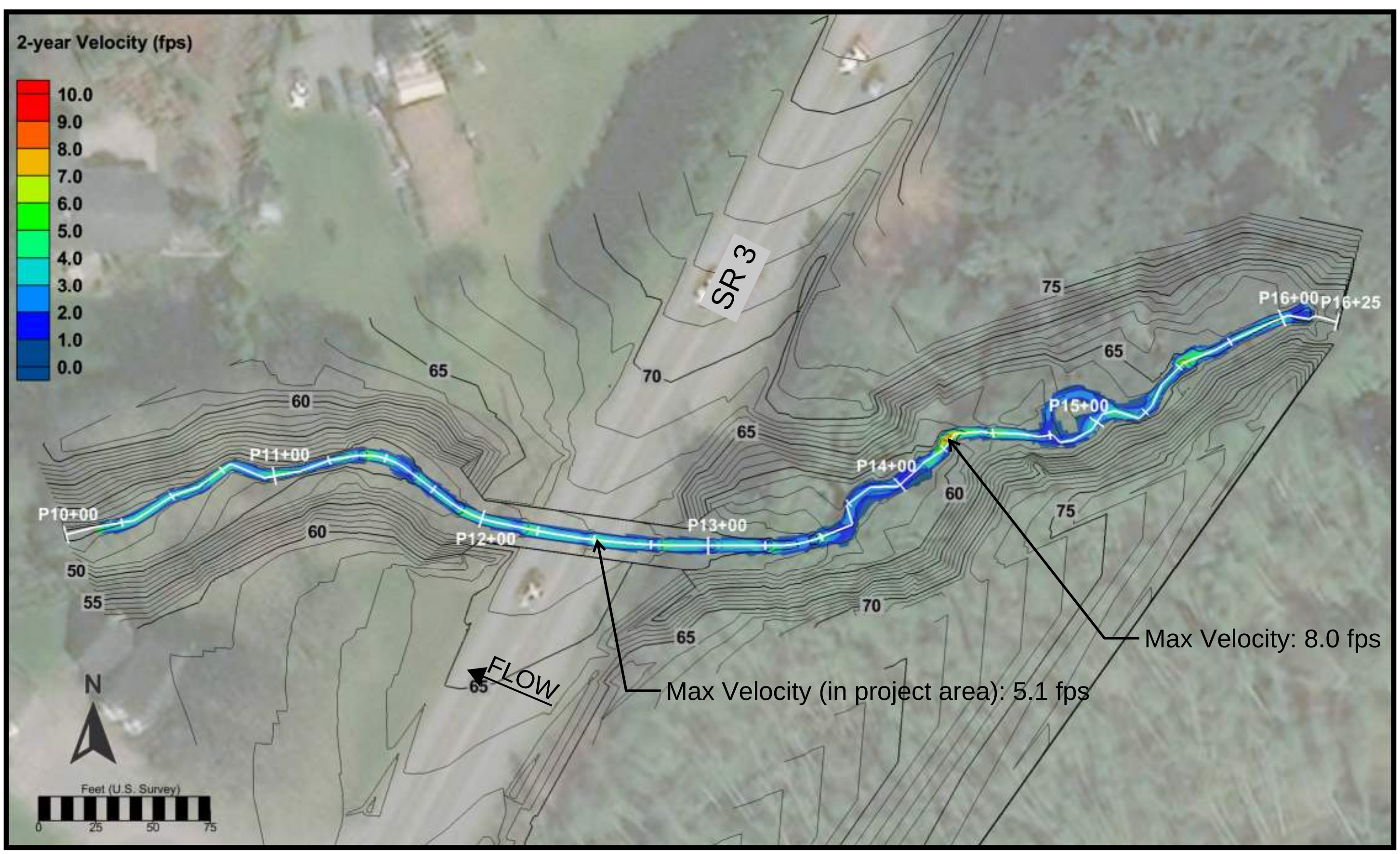
Natural Condition Water Surface Profile (ft, NAVD88)



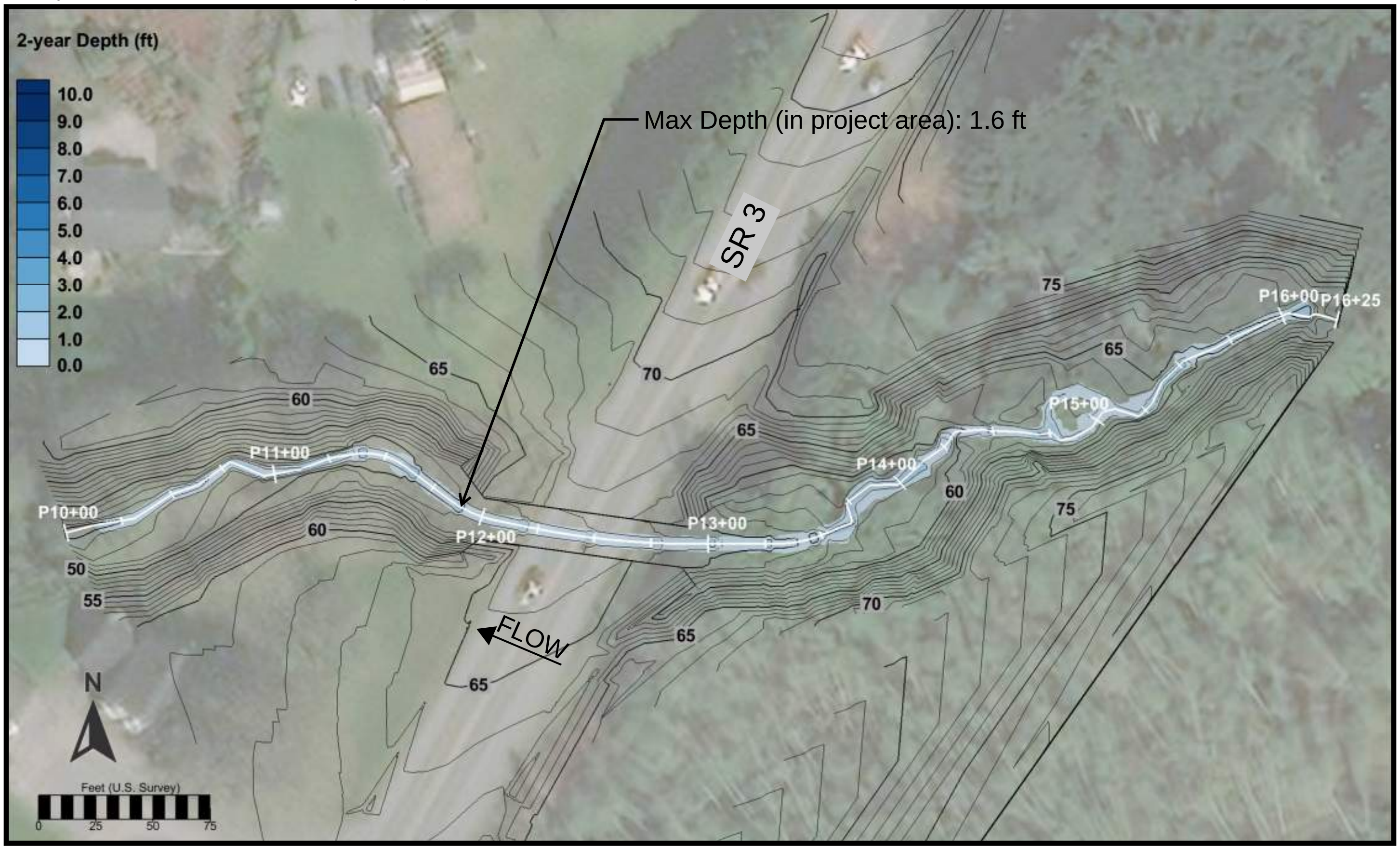
Proposed Condition — Q2 Water Surface Elevations (ft, NAVD 88)



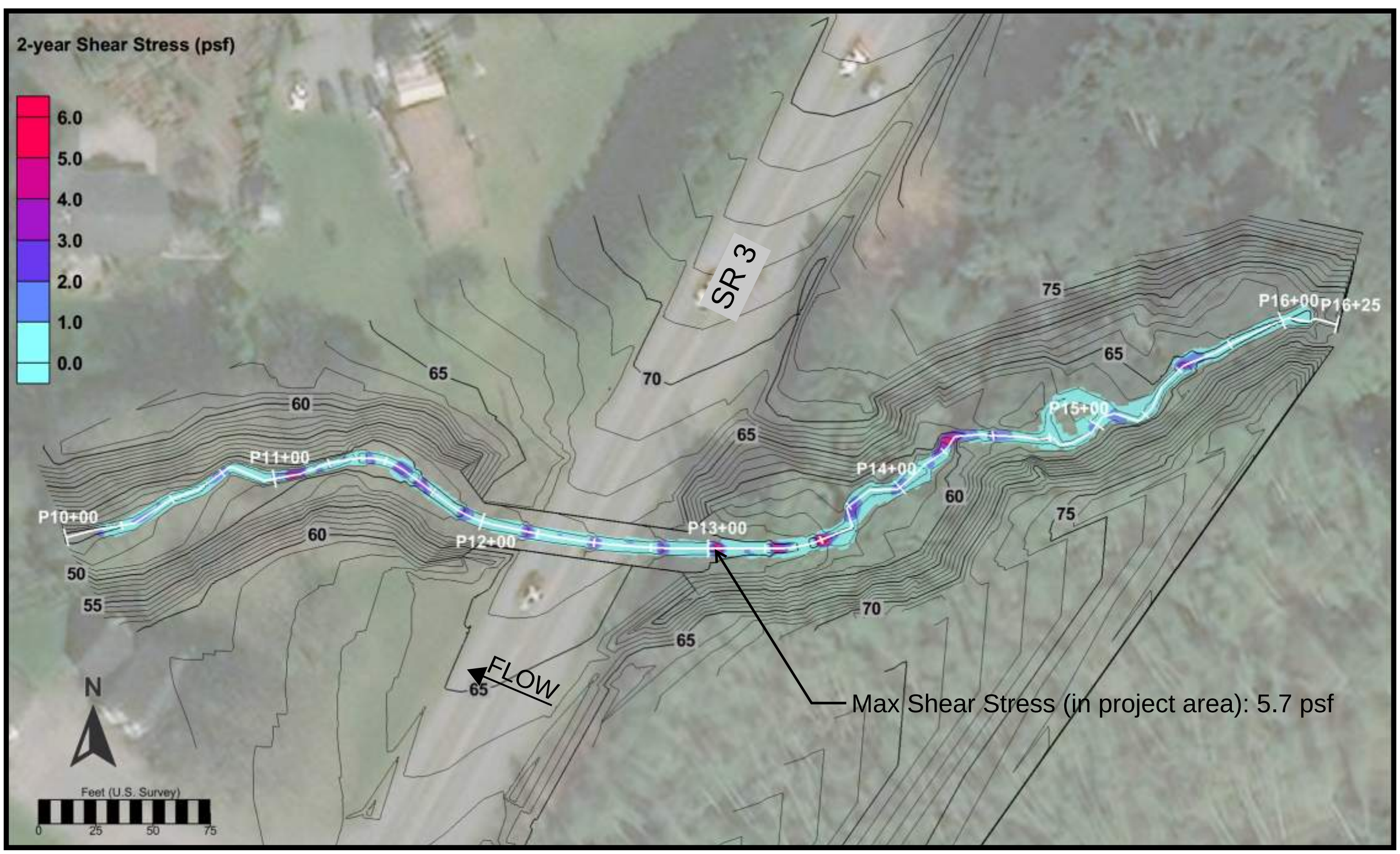
Proposed Condition—Q2 Velocity (fps)



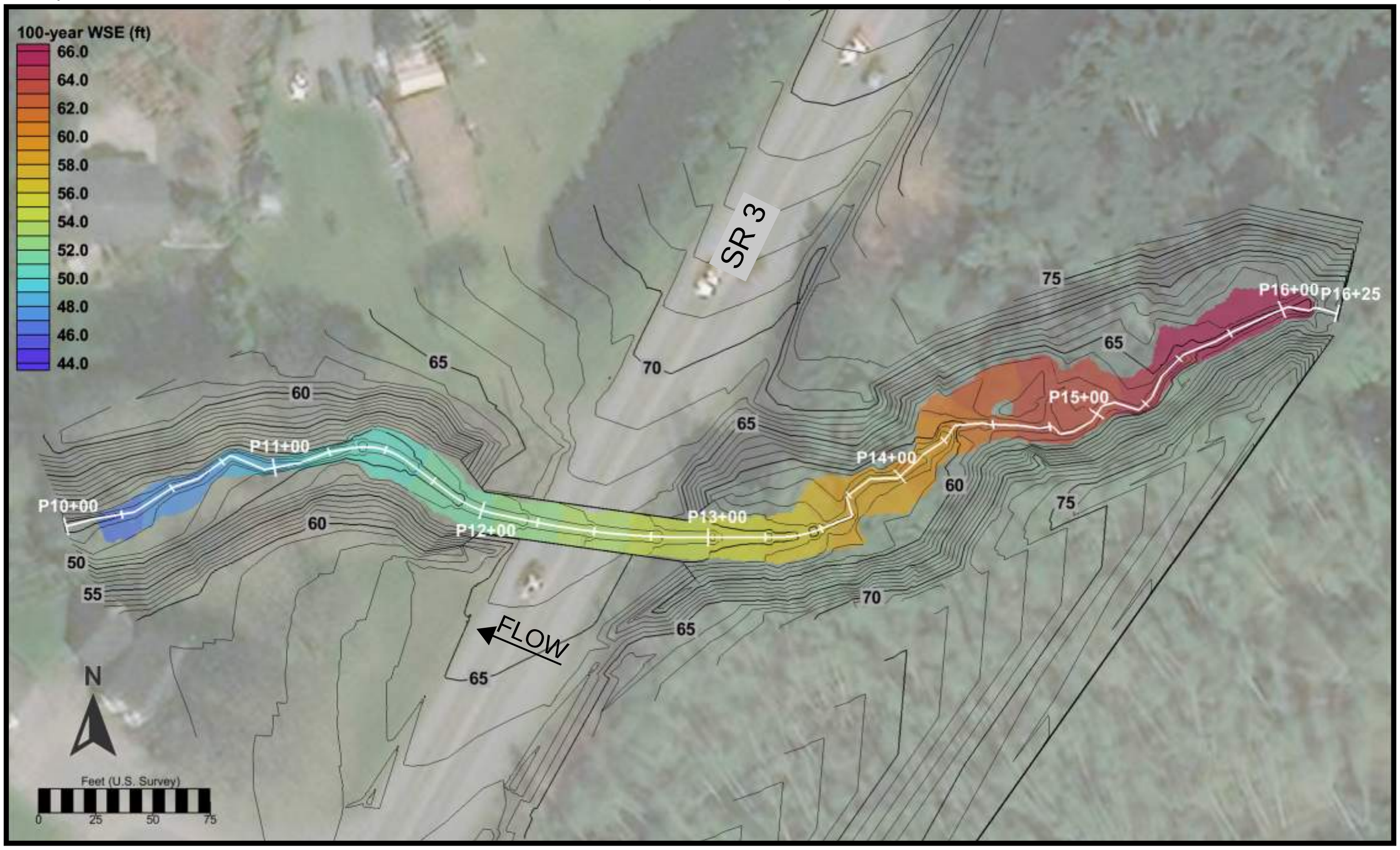
Proposed Condition — Q2 Depth (ft)



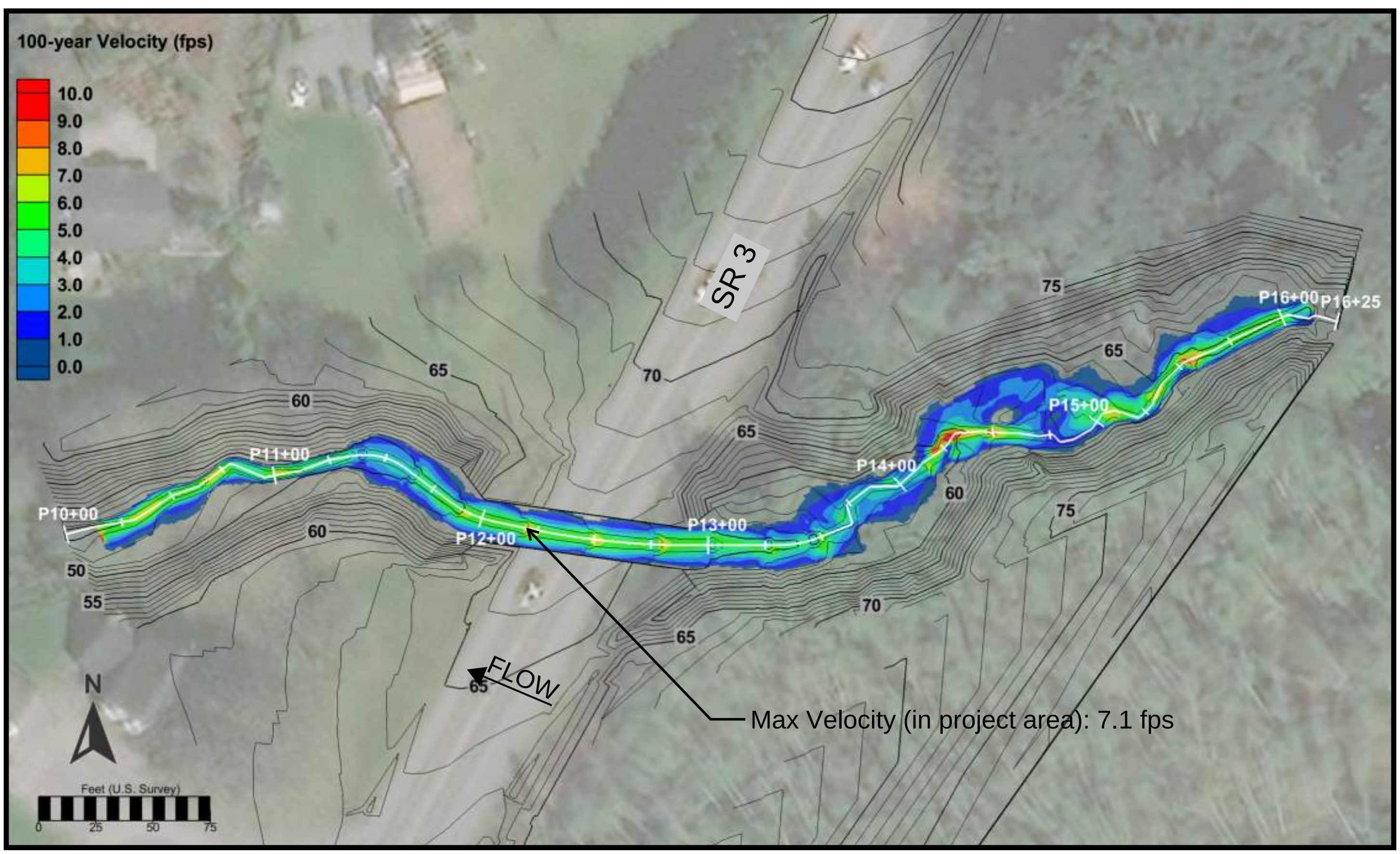
Proposed Condition—Q2 Shear Stress (psf)



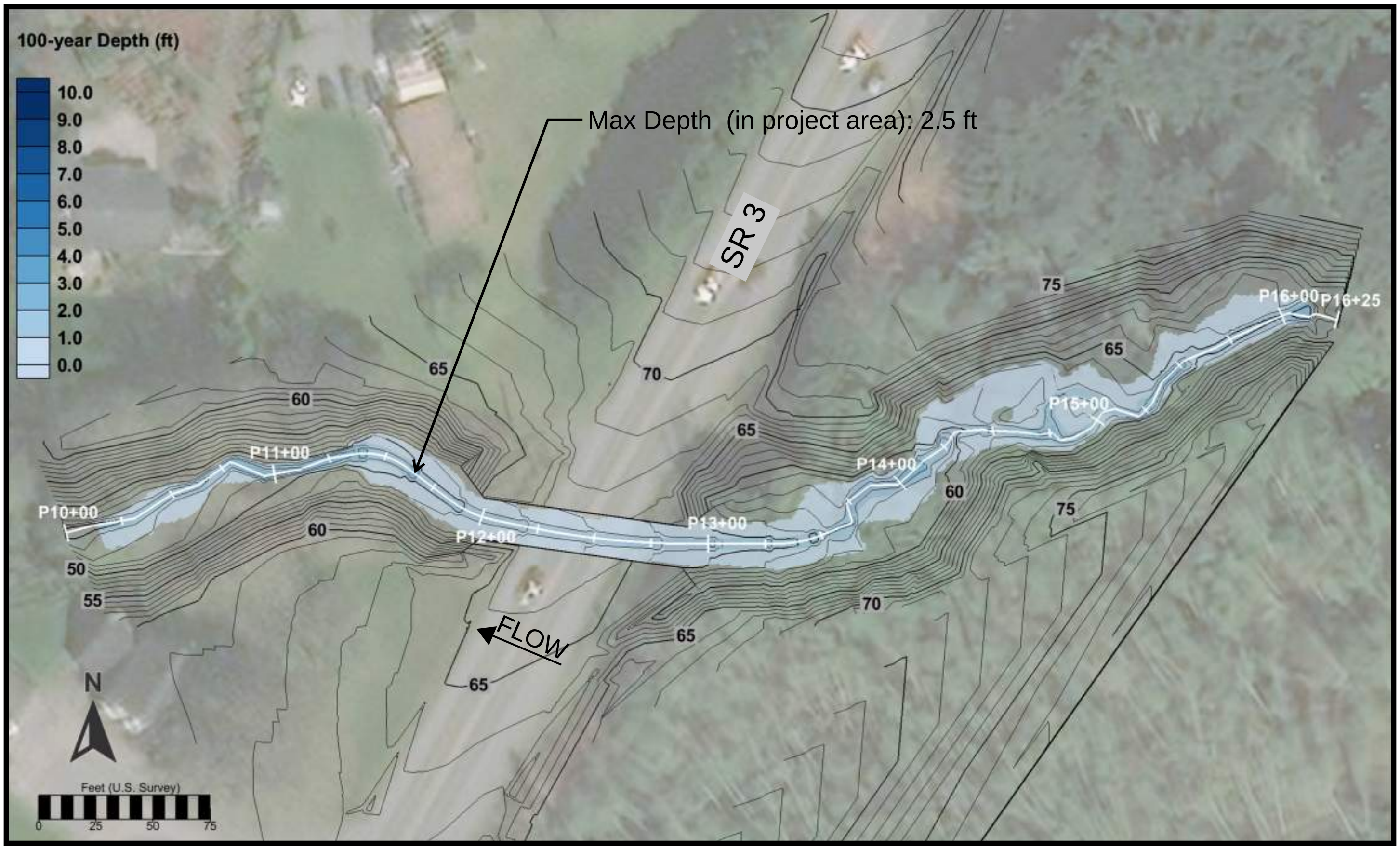
Proposed Condition — Q100 Water Surface Elevations (ft, NAVD 88)



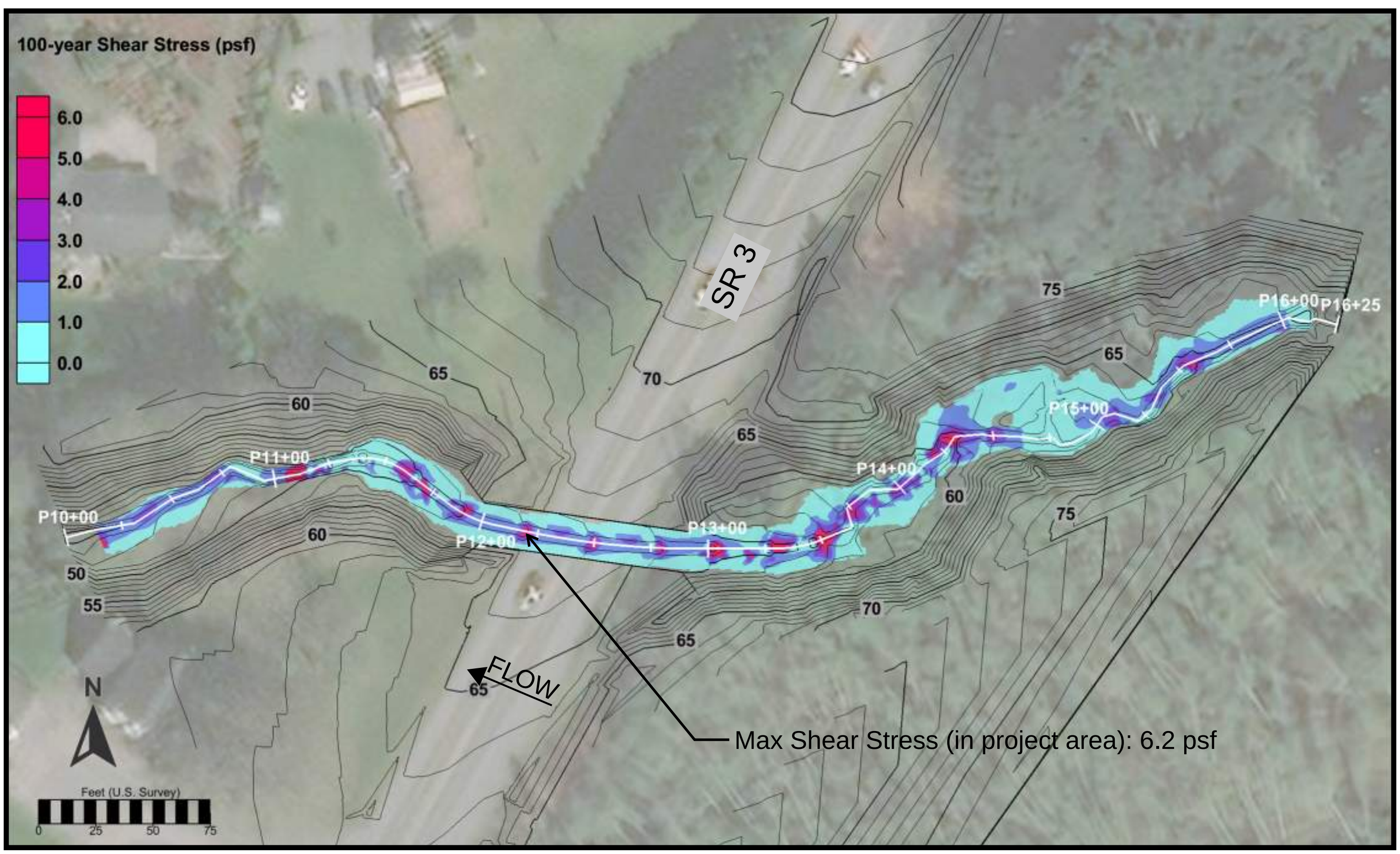
Proposed Condition — Q100 Velocity (fps)



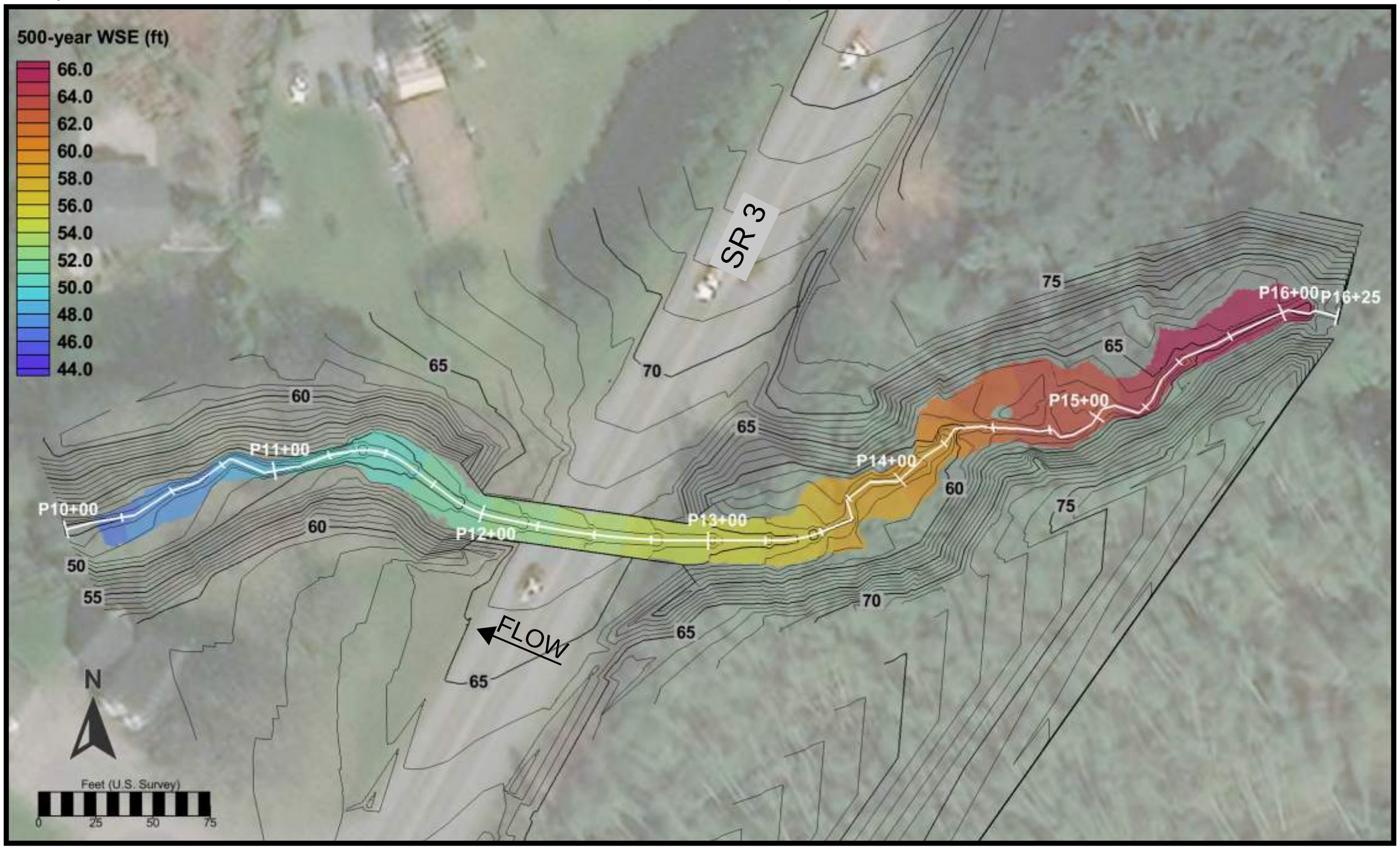
Proposed Condition— Q100 Depth (ft)



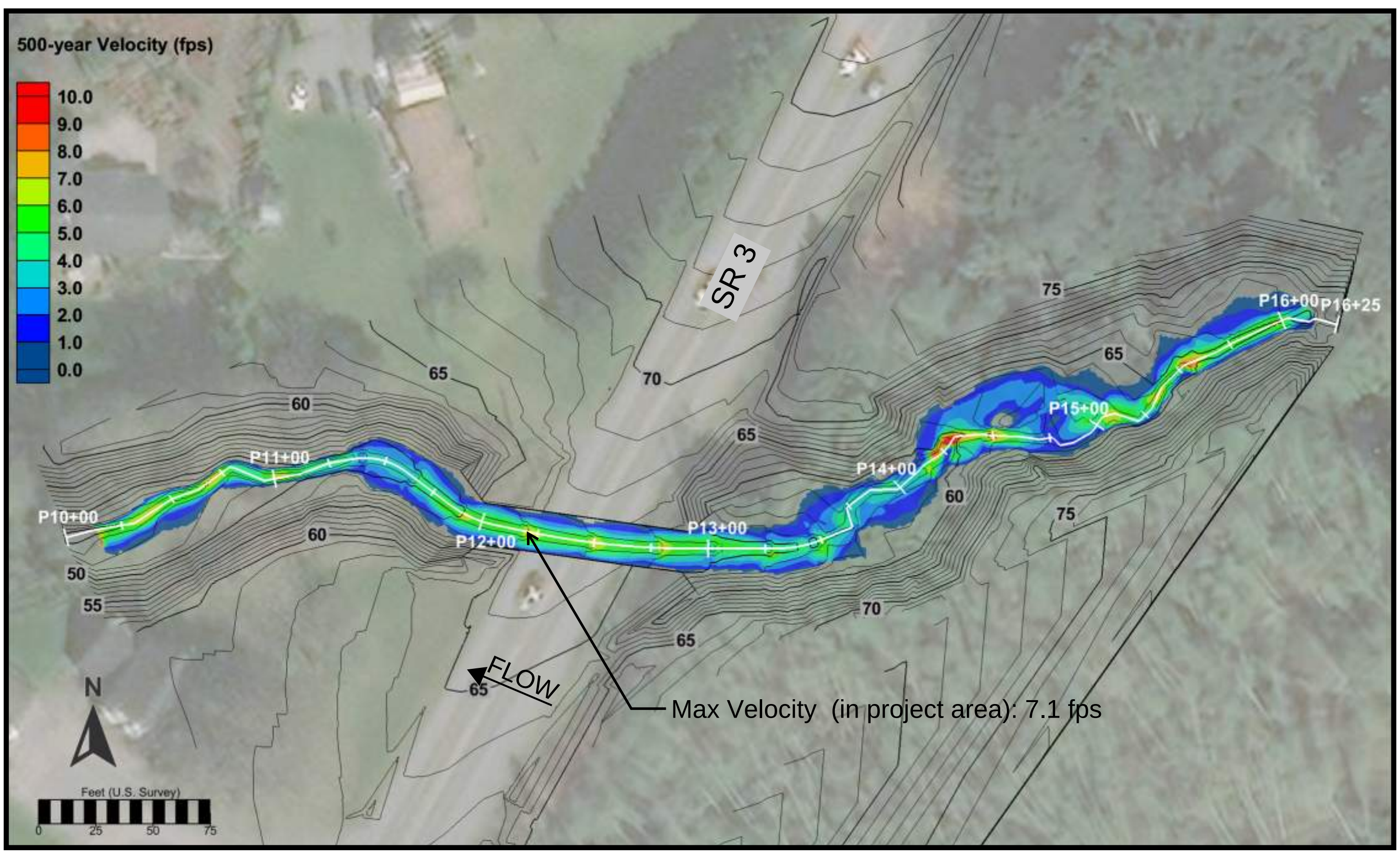
Proposed Condition— Q100 Shear Stress (psf)



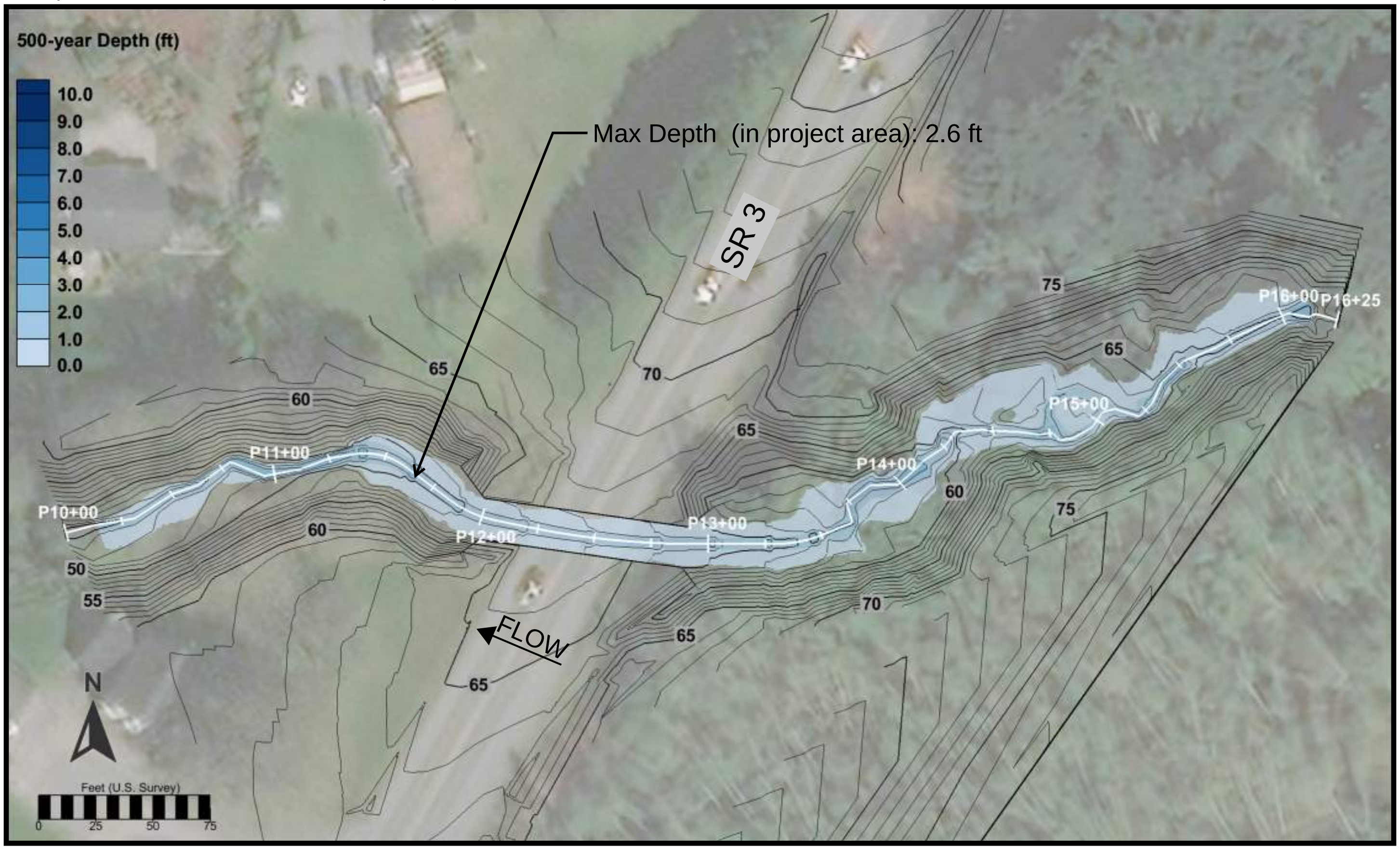
Proposed Condition — Q500 Water Surface Elevations (ft, NAVD 88)



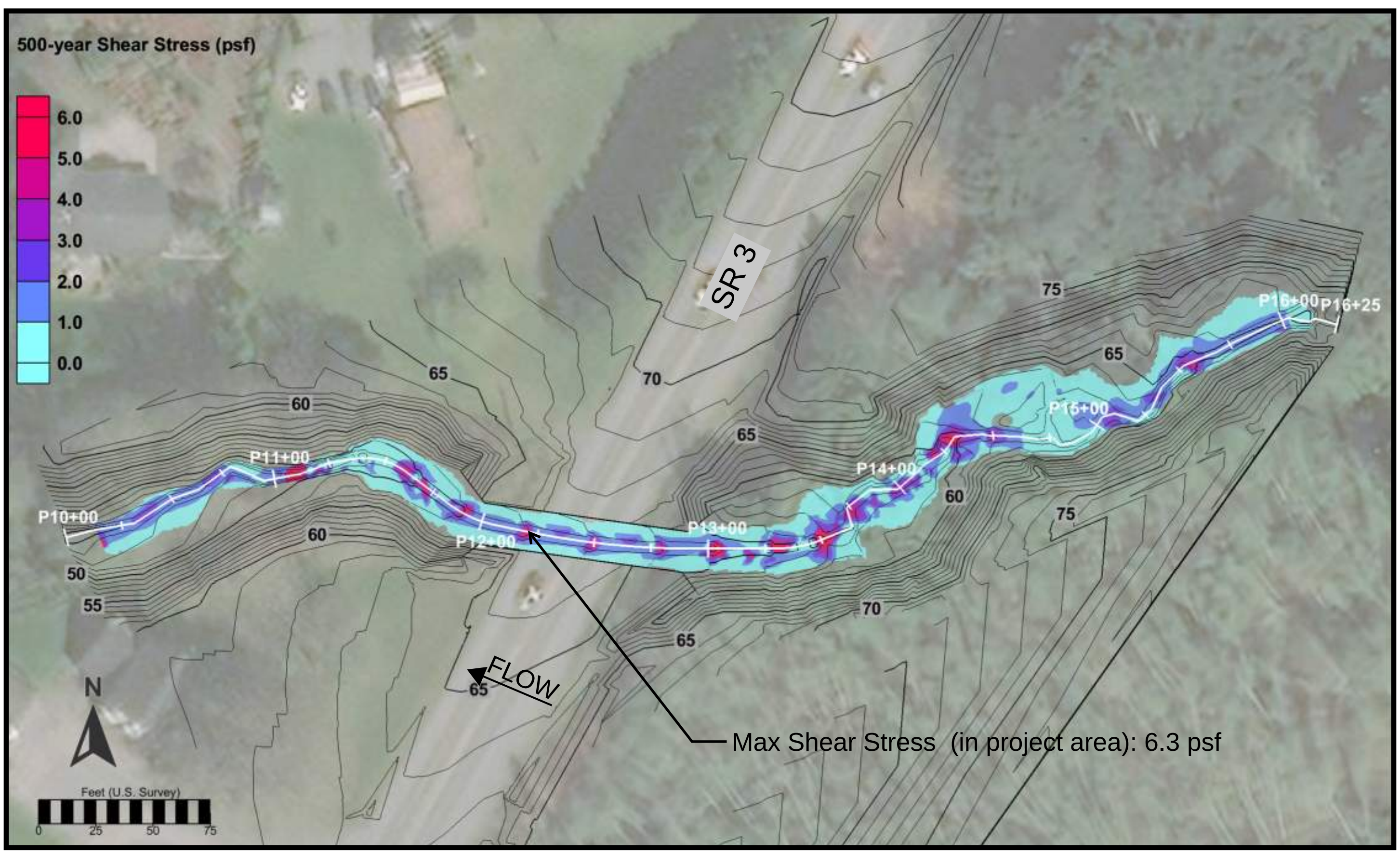
Proposed Condition — Q500 Velocity (fps)



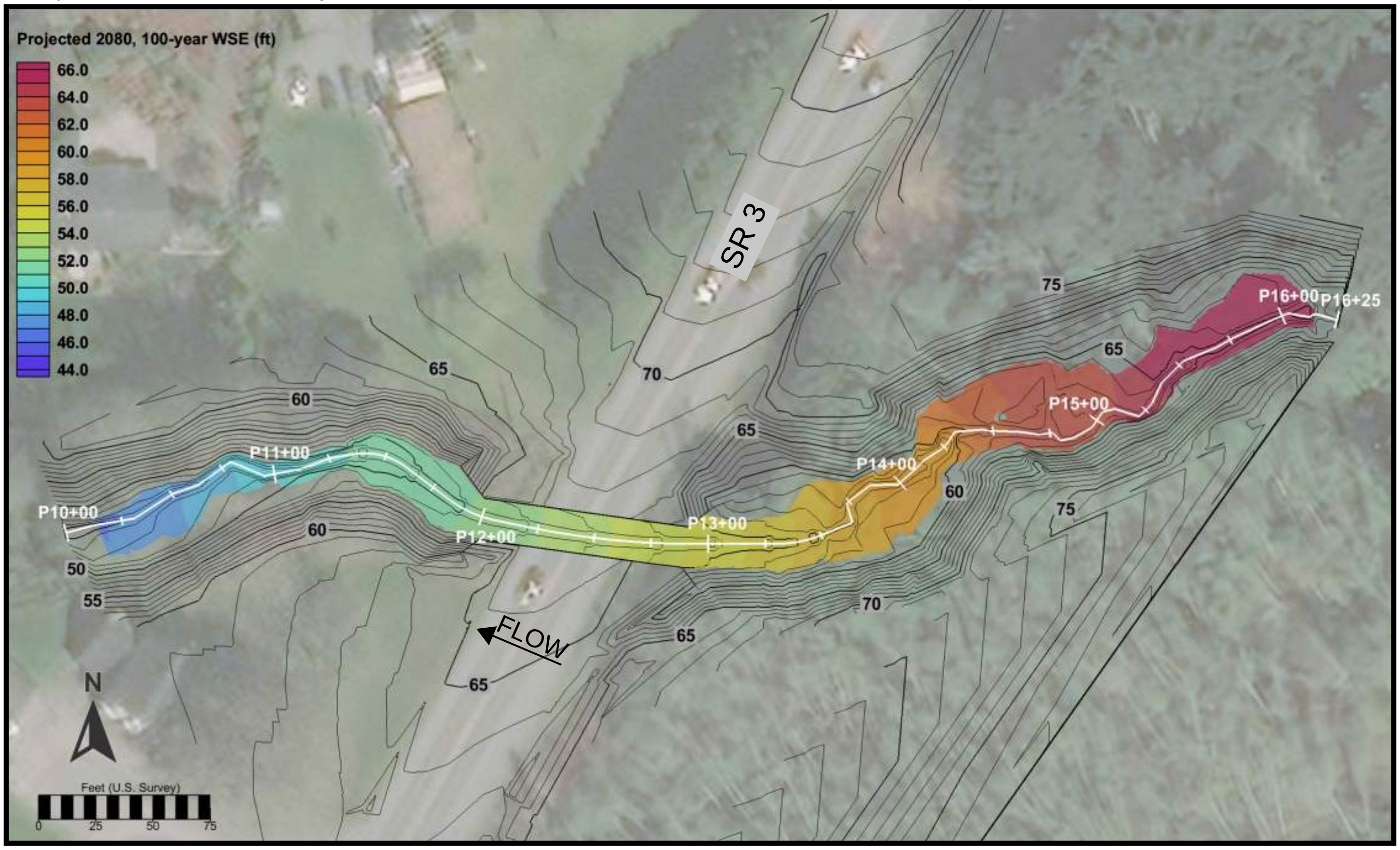
Proposed Condition— Q500 Depth (ft)



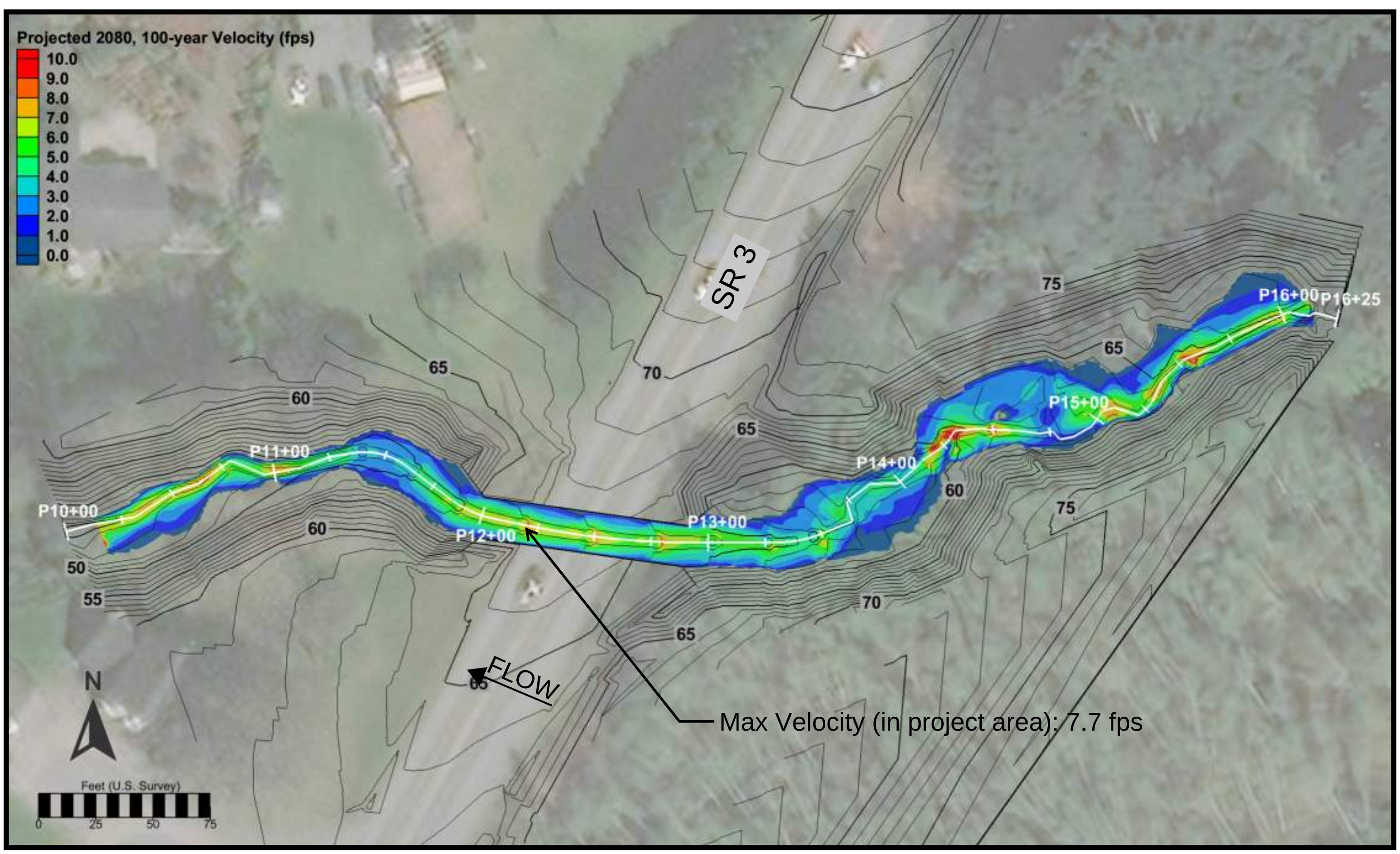
Proposed Condition— Q500 Shear Stress (psf)



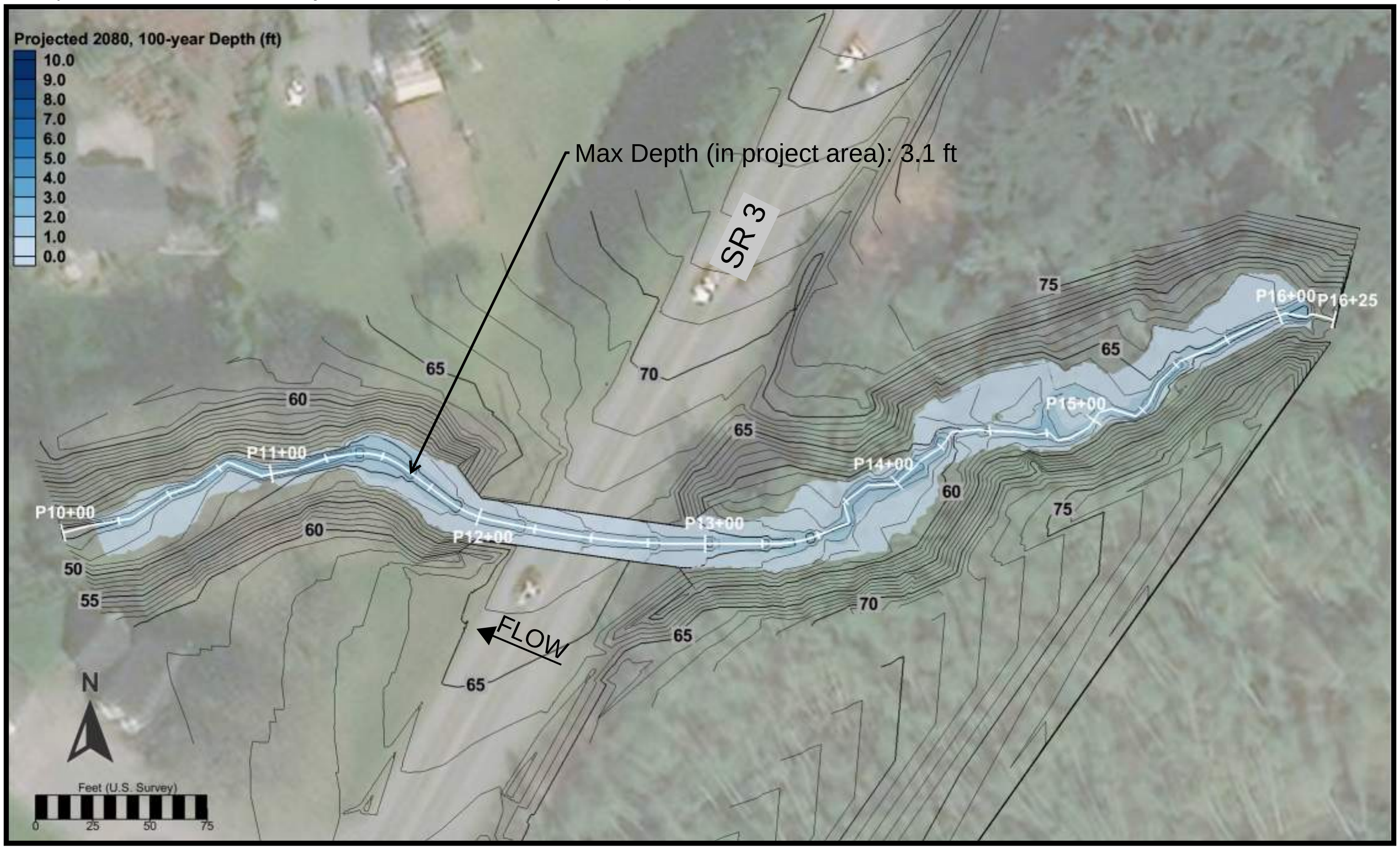
Proposed Condition — Projected 2080 Q100 Water Surface Elevations (ft, NAVD 88)



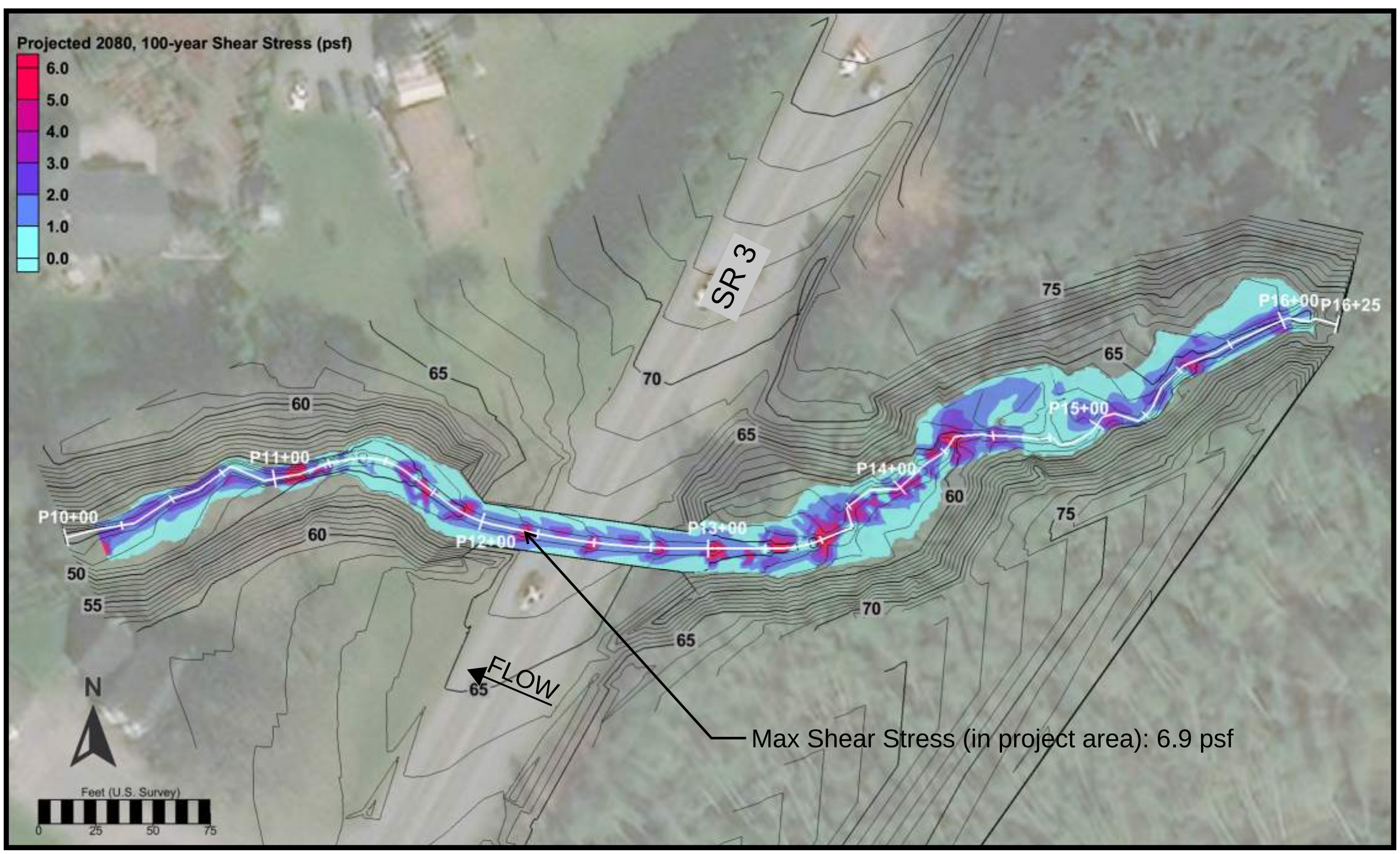
Proposed Condition — Projected 2080 Q100 Velocity (fps)



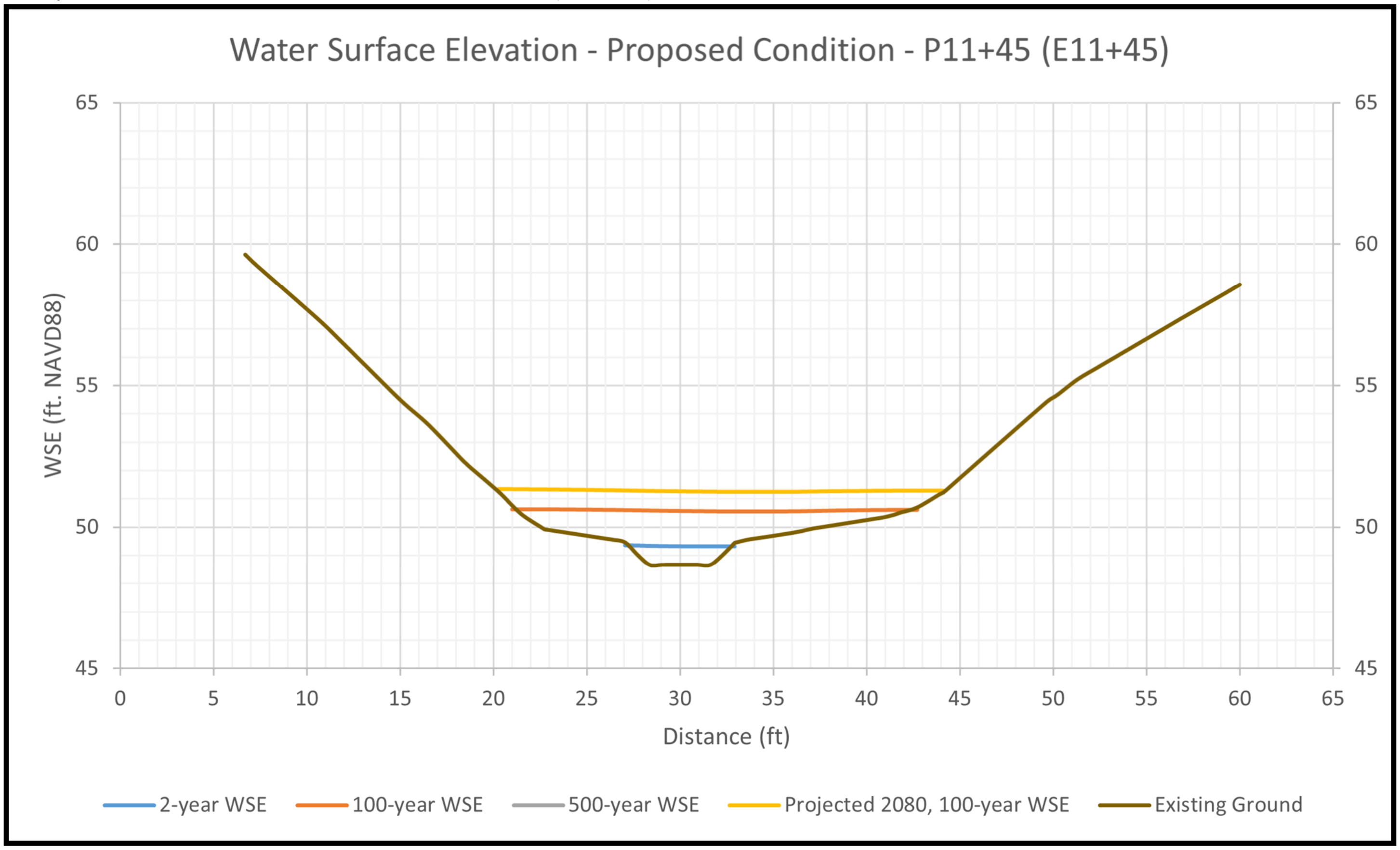
Proposed Condition— Projected 2080 Q100 Depth (ft)



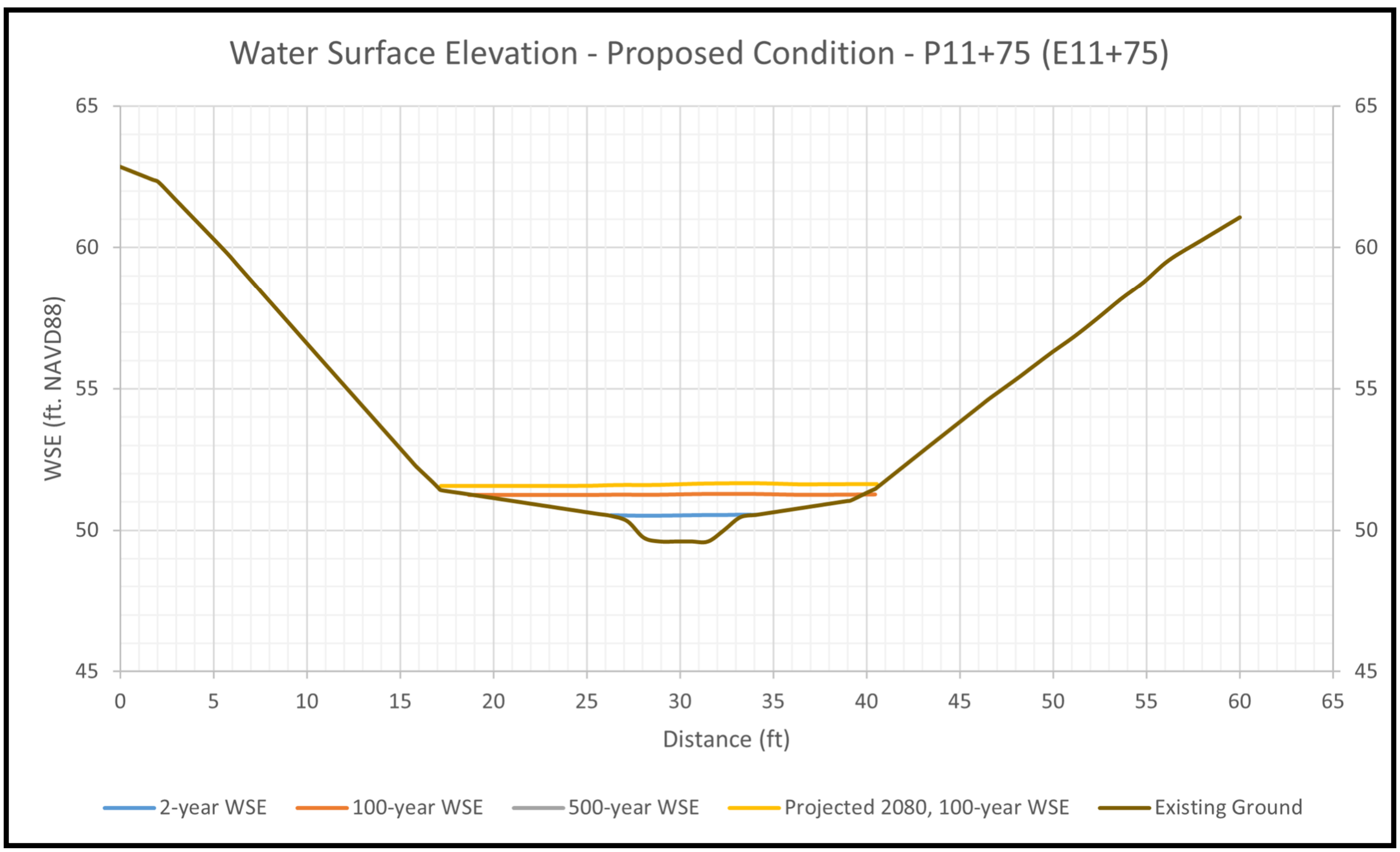
Proposed Condition— Projected 2080 Q100 Shear Stress (psf)



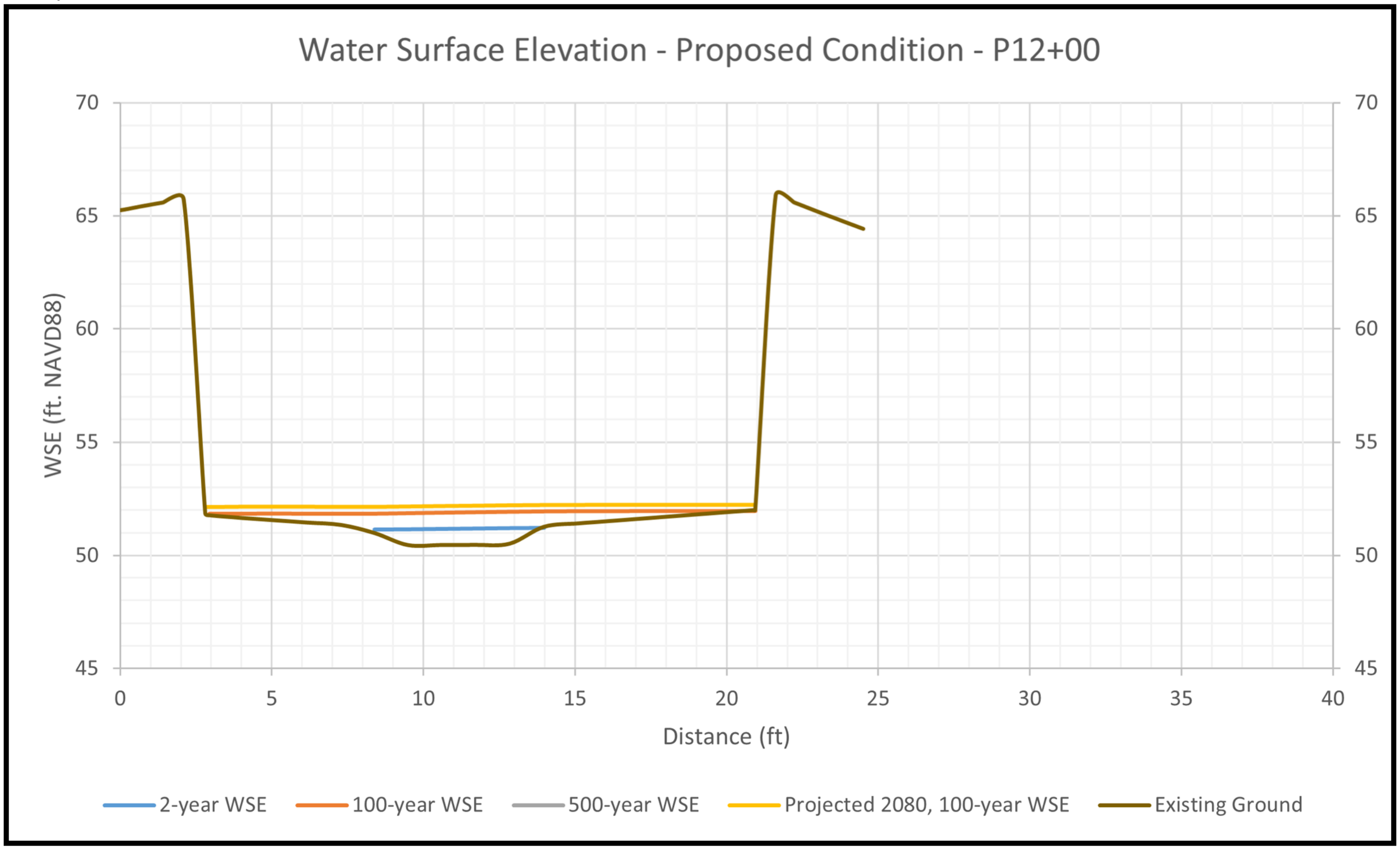
Proposed Condition Section — Station P11+45 (E11+45)



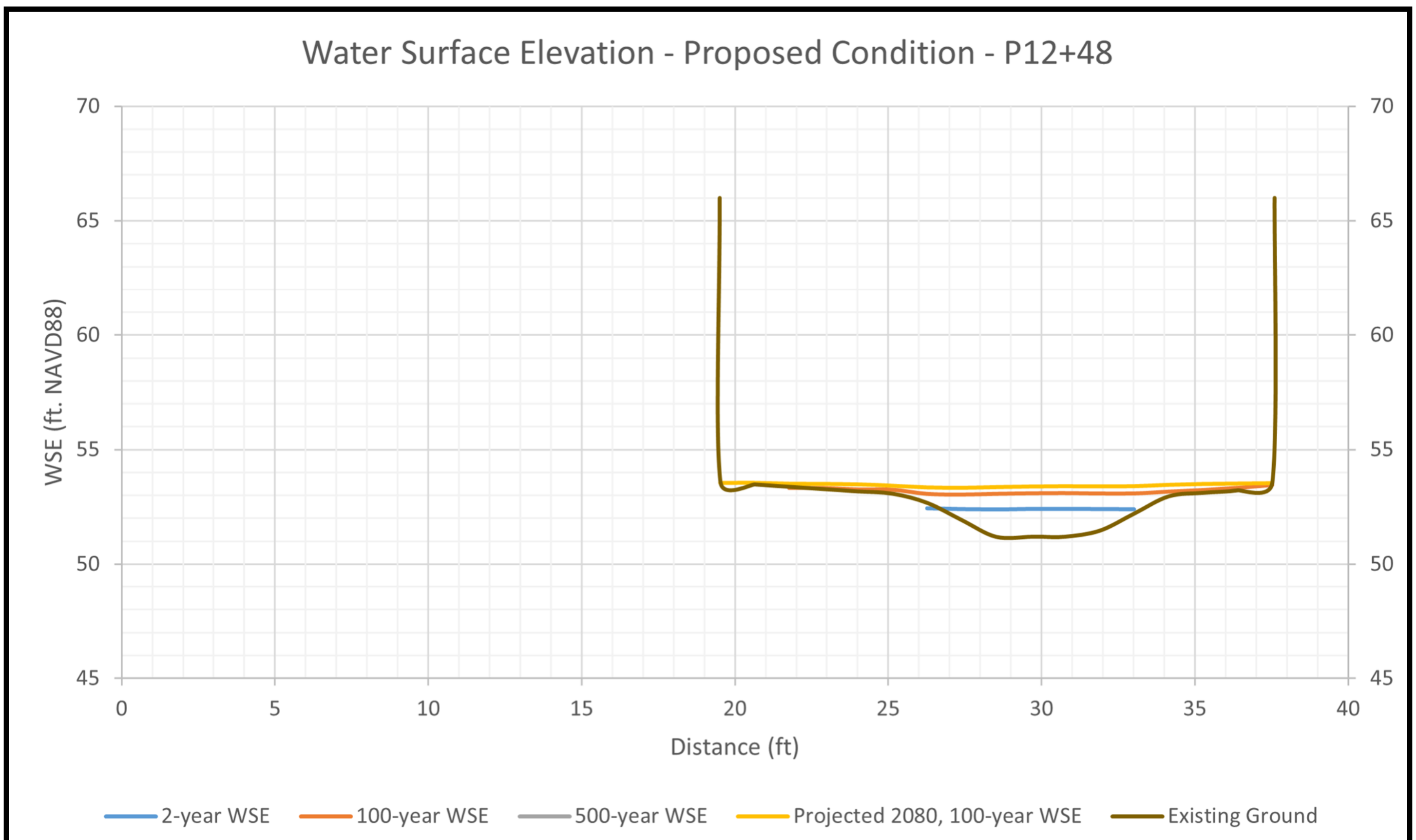
Proposed Condition Section — Station P11+75 (E11+75)



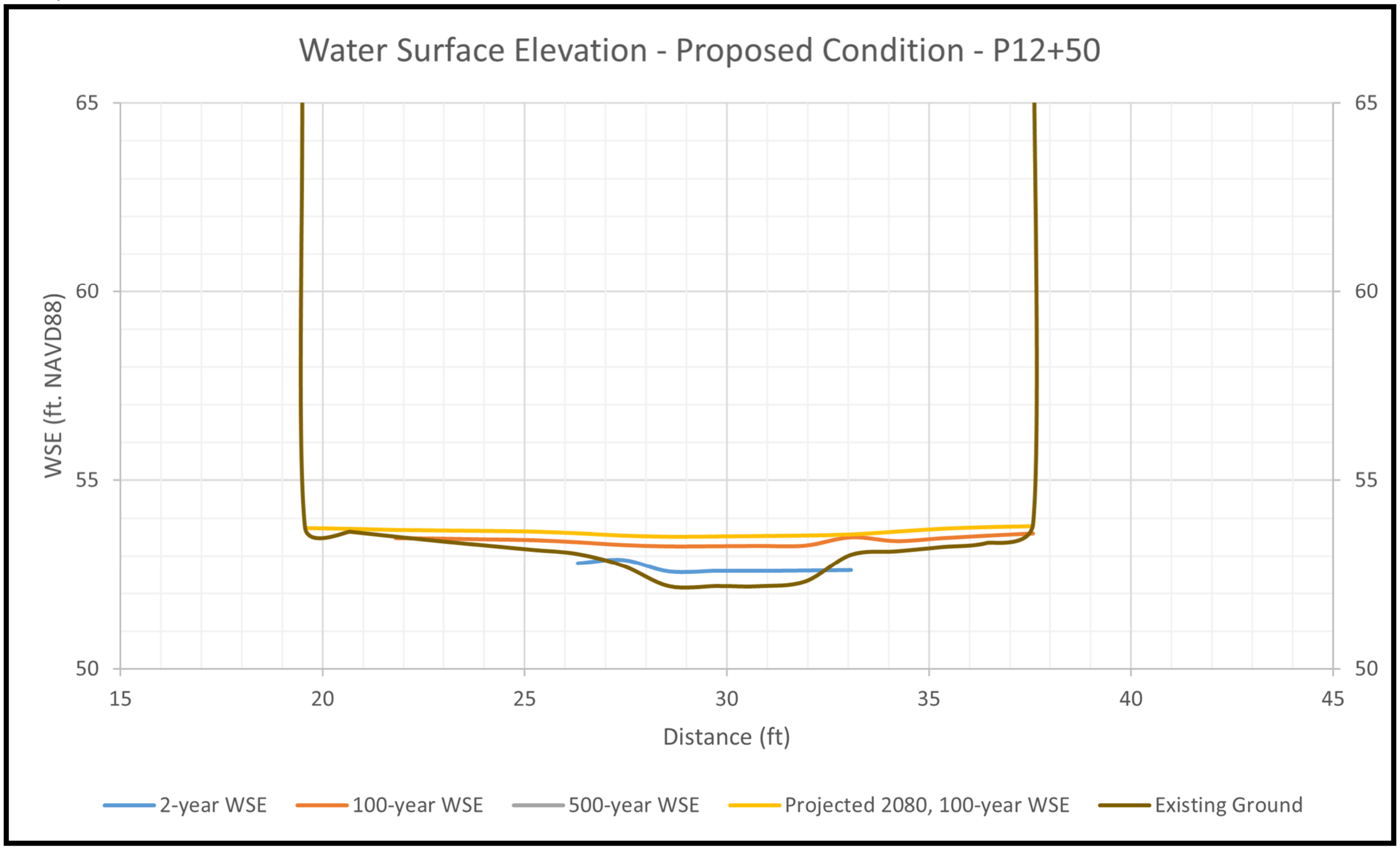
Proposed Condition Section — Station P12+00



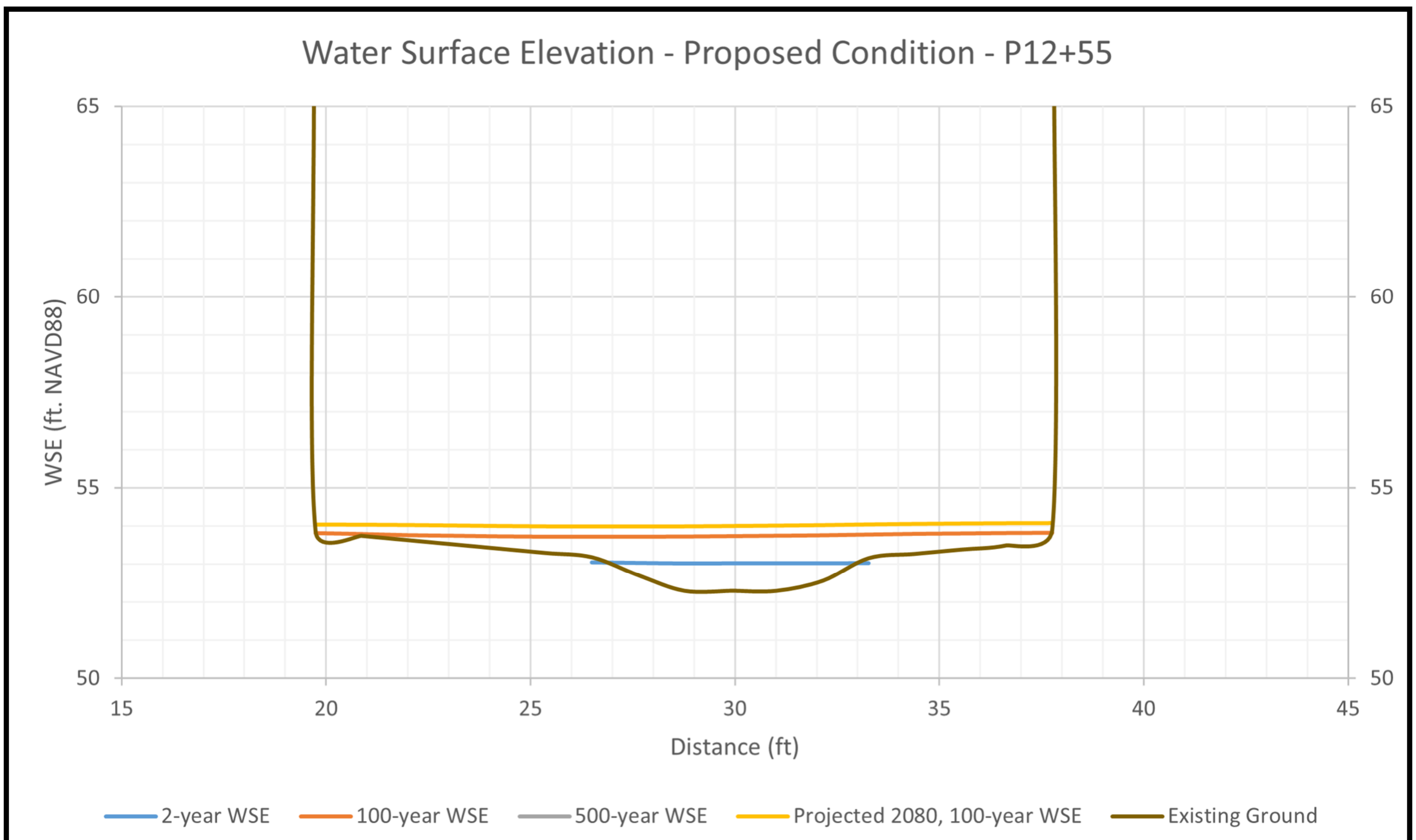
Proposed Condition Section — Station P12+48



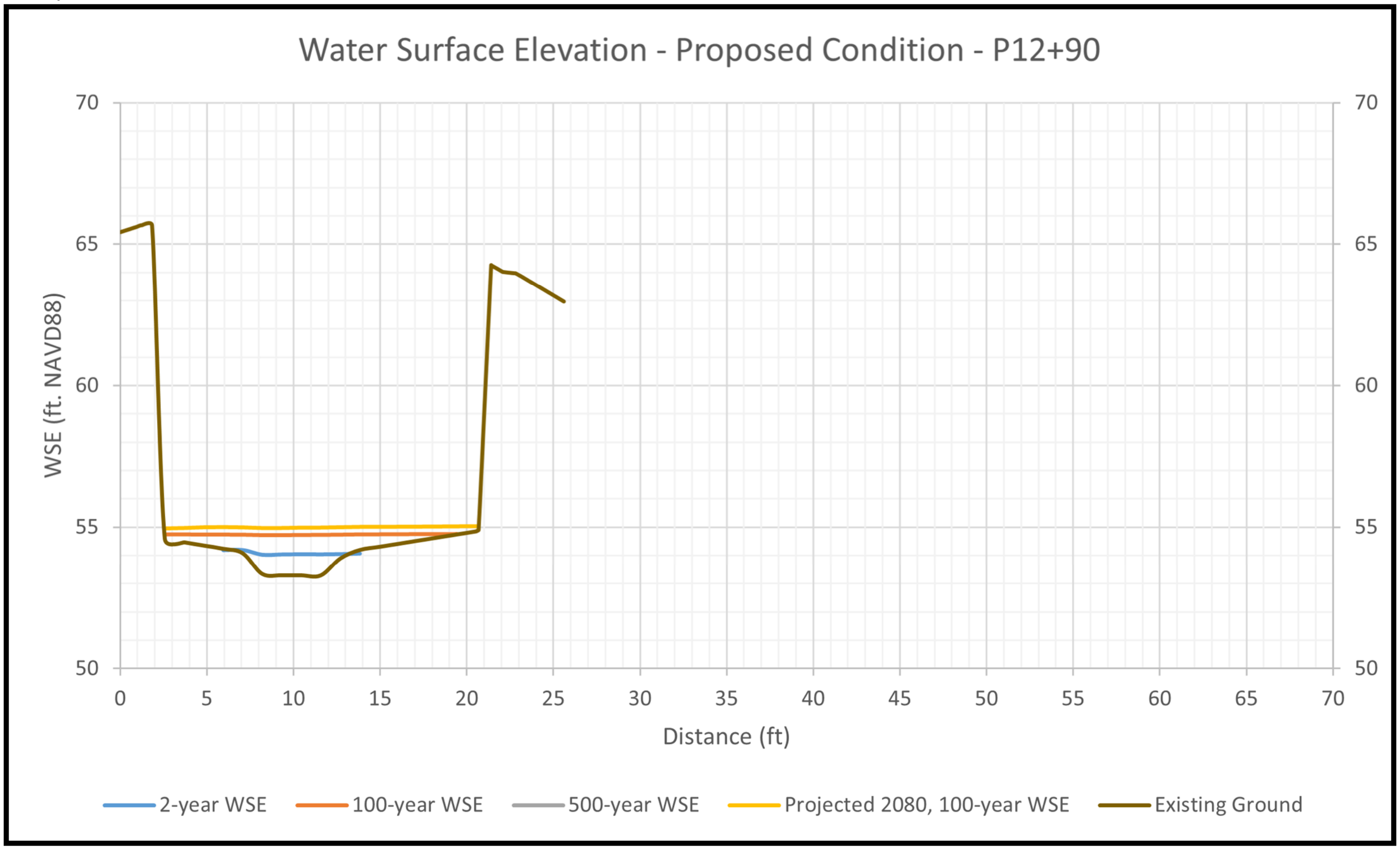
Proposed Condition Section — Station P12+50



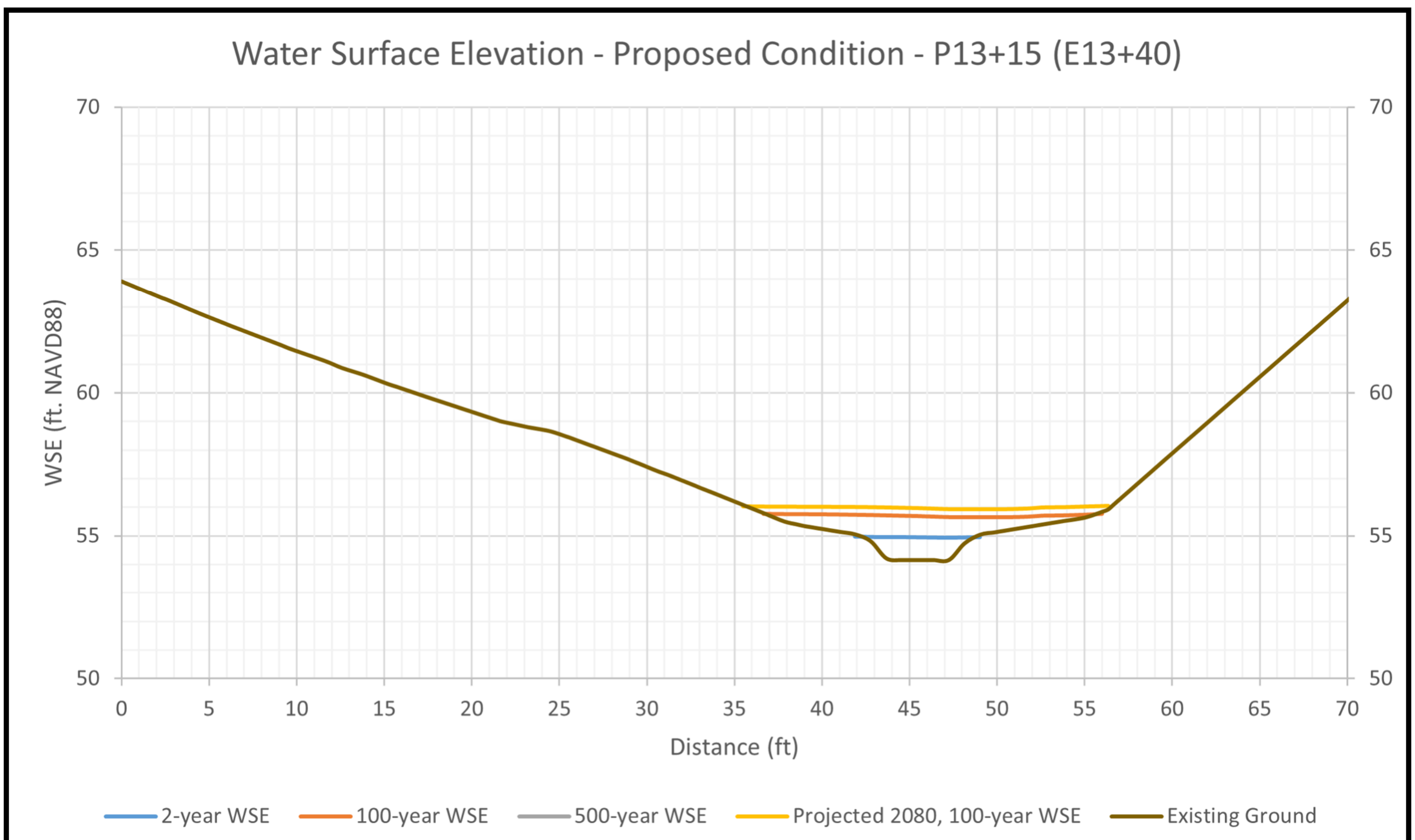
Proposed Condition Section — Station P12+55



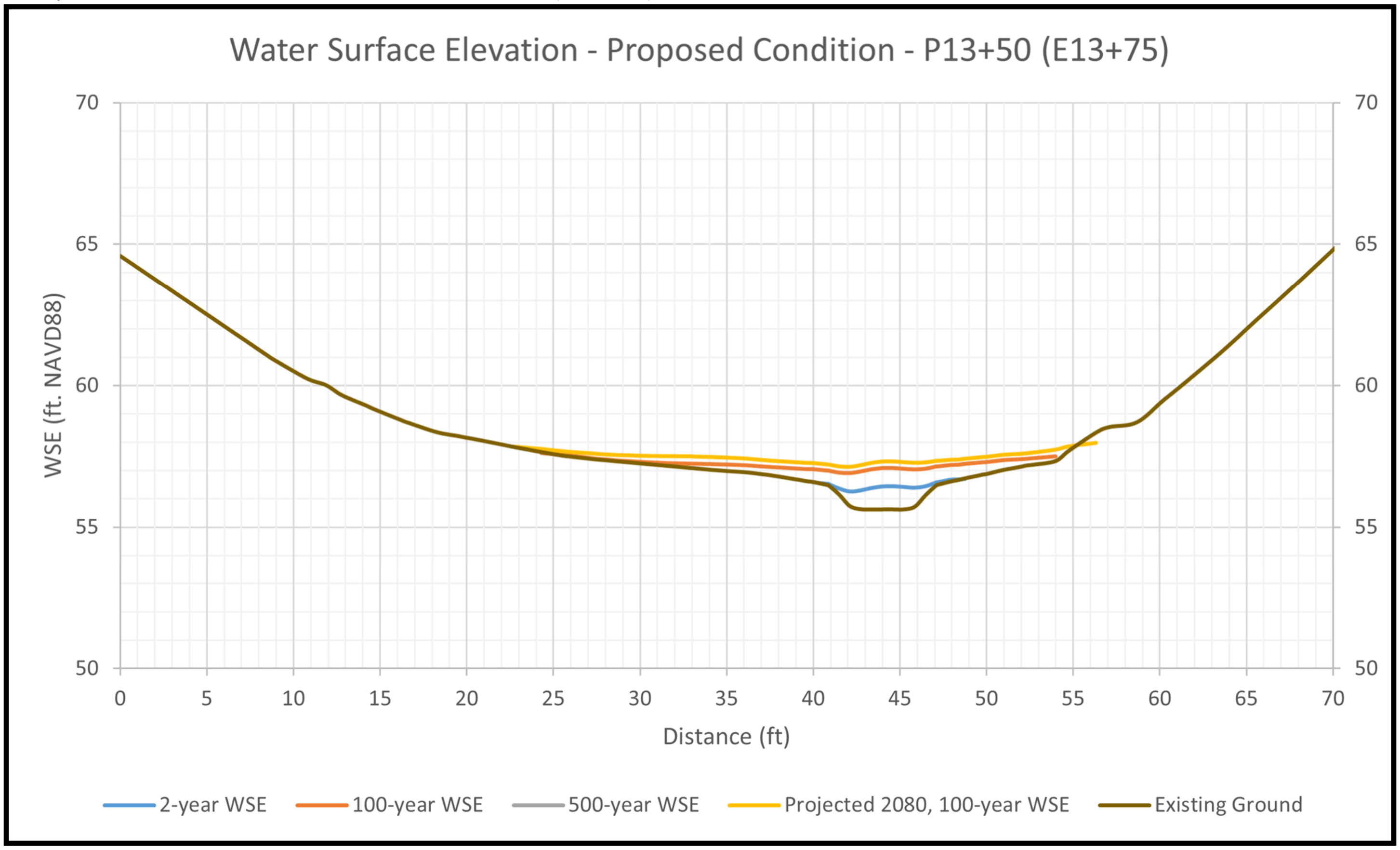
Proposed Condition Section — Station P12+90



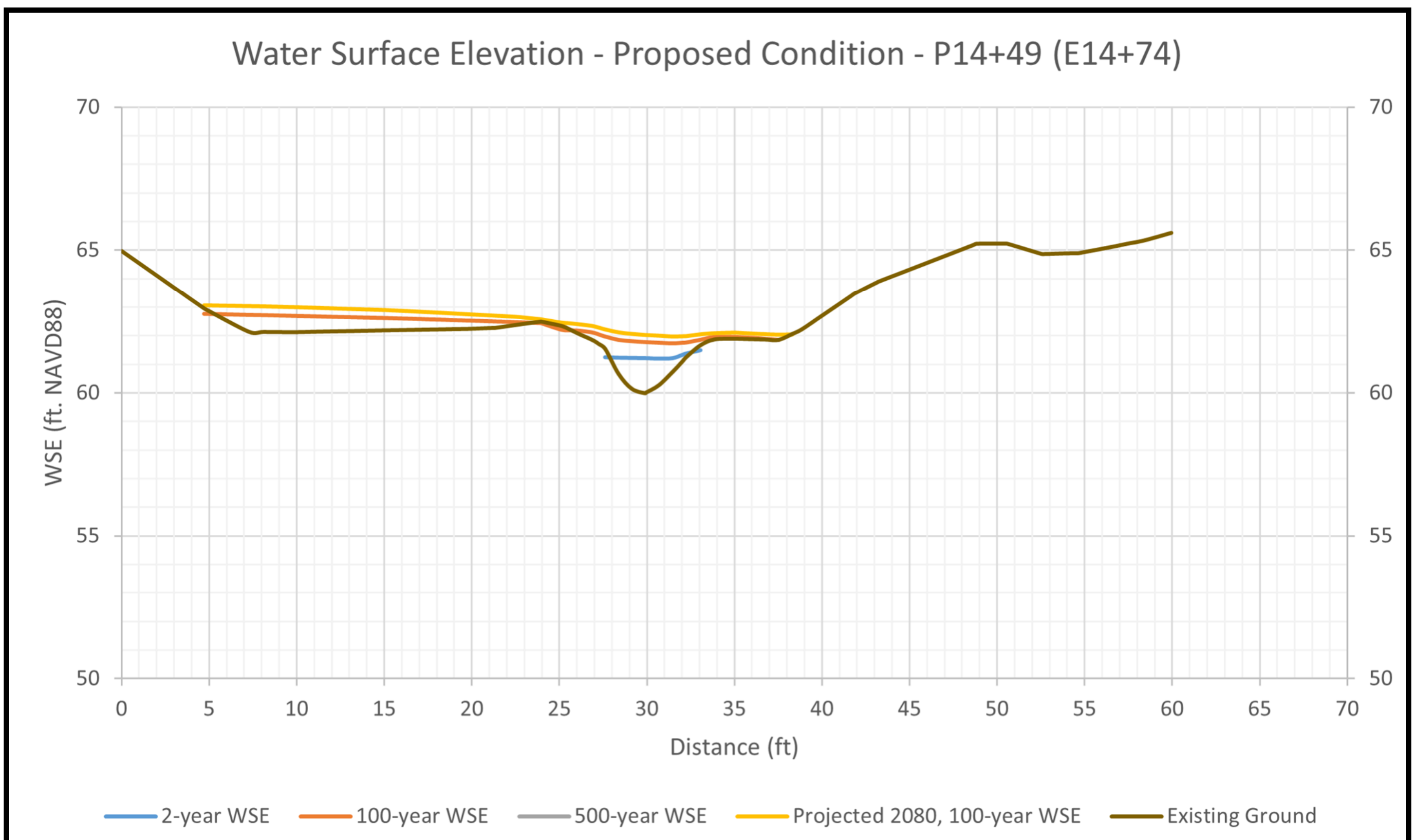
Proposed Condition Section — Station P13+15 (E13+40)



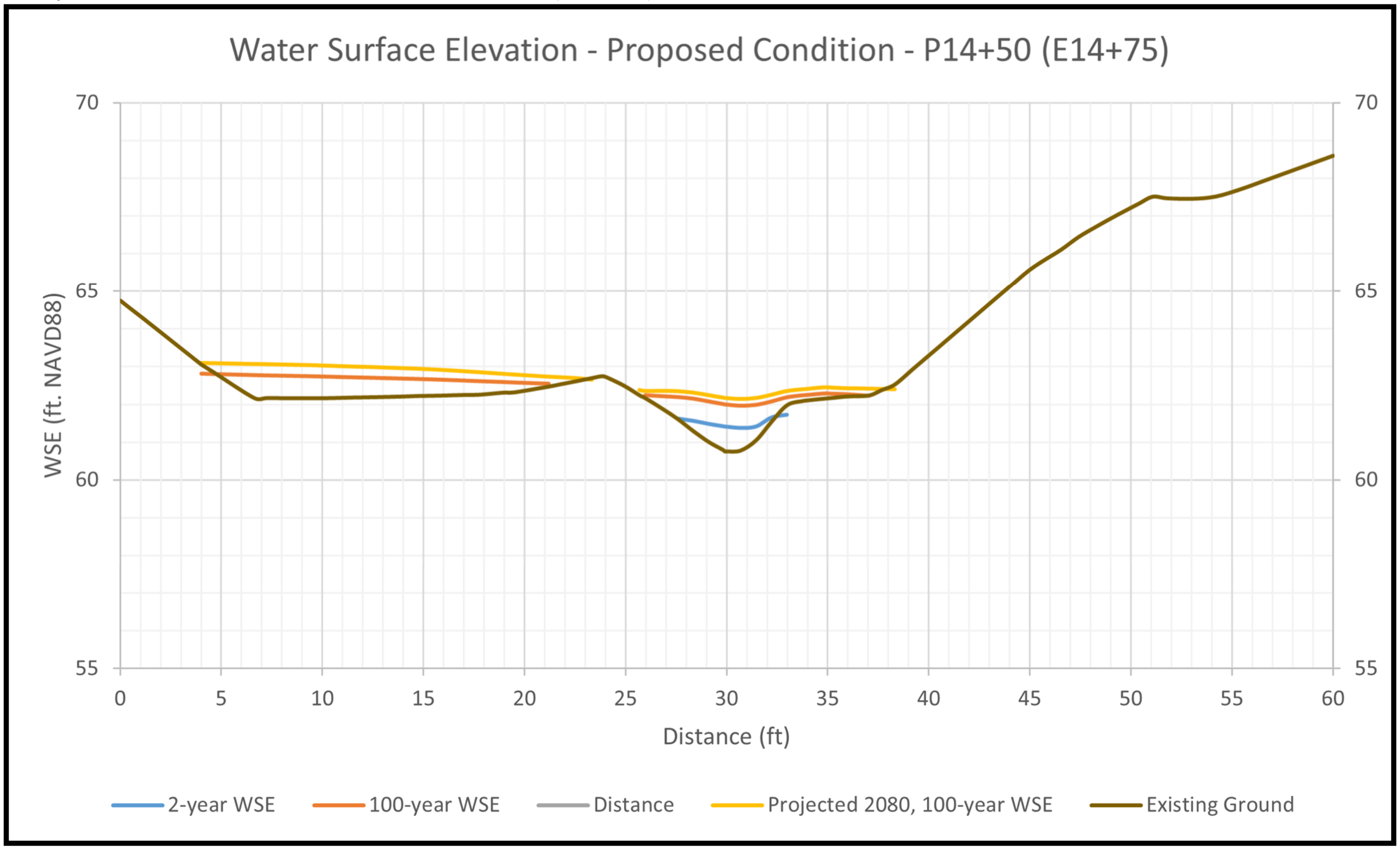
Proposed Condition Section — Station P13+50 (E13+75)



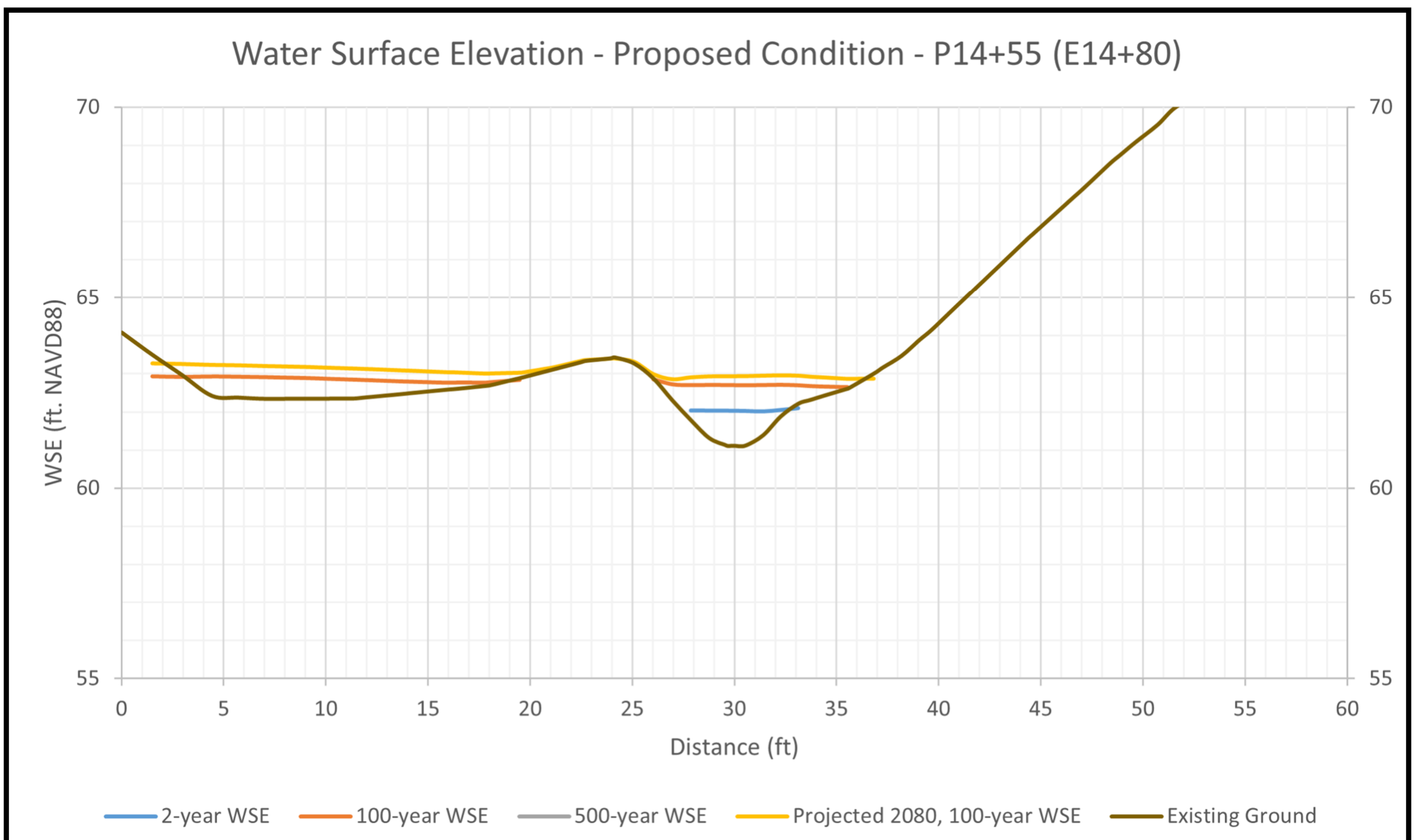
Proposed Condition Section — Station P14+49 (E14+74)



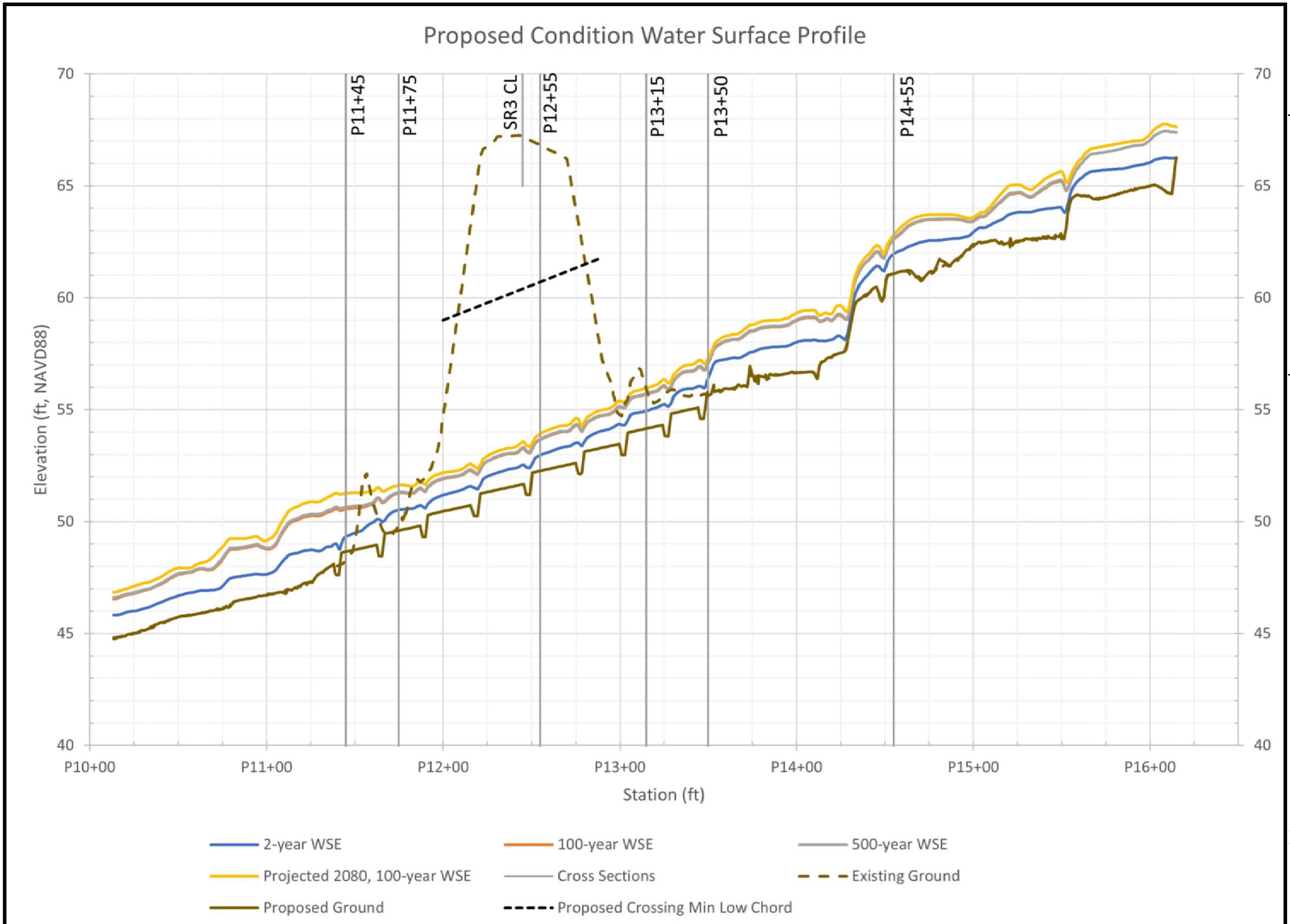
Proposed Condition Section — Station P14+50 (E14+75)



Proposed Condition Section — Station P14+55 (E14+80)

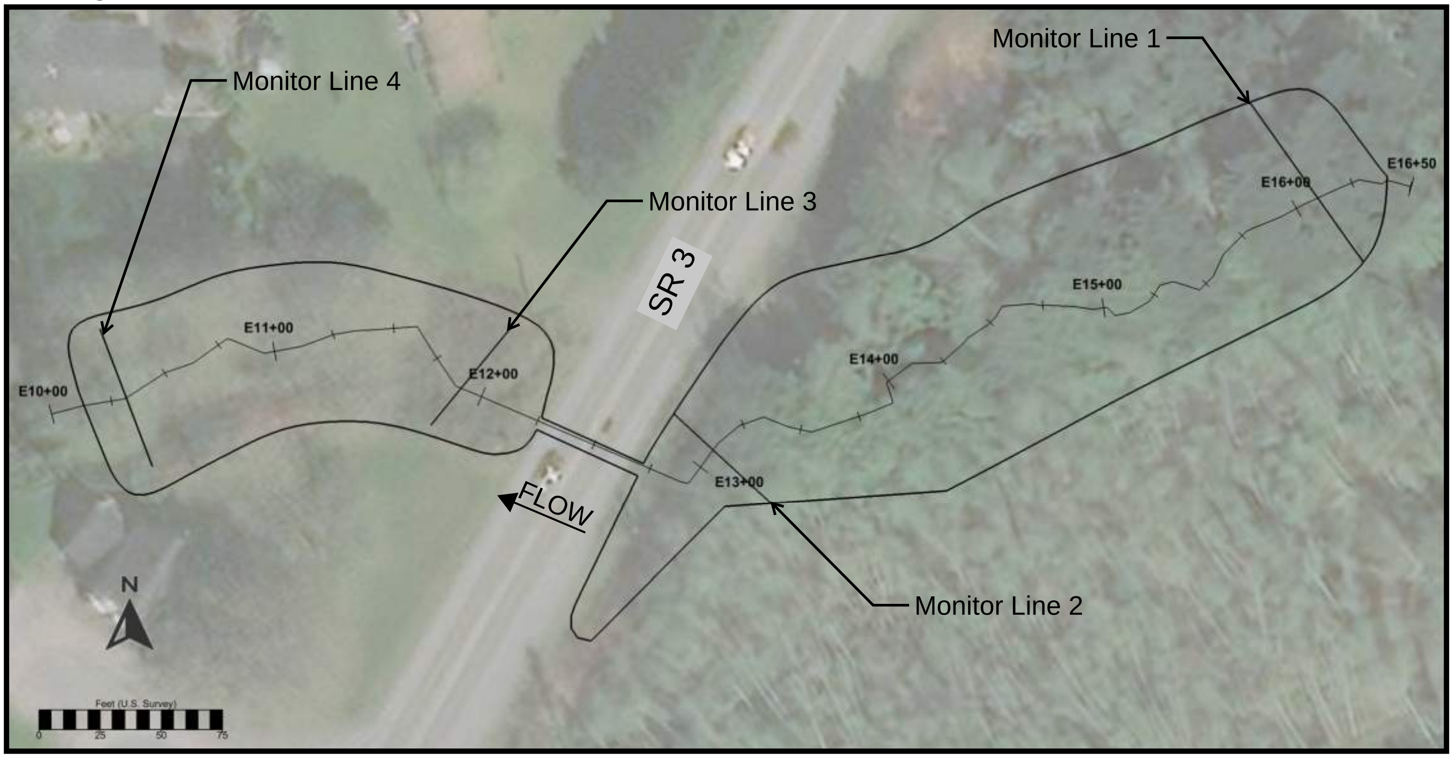


Proposed Condition Water Surface Profile (ft, NAVD88)

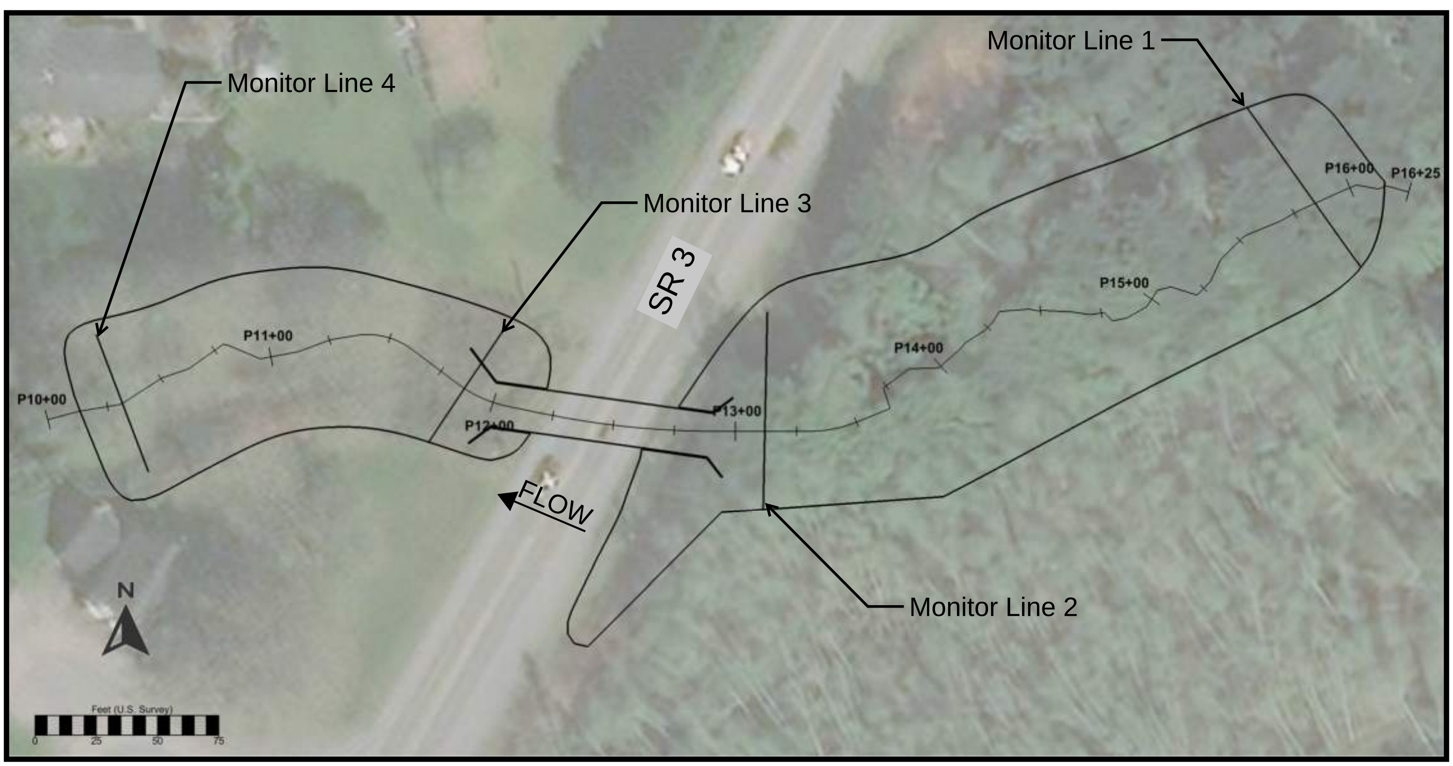


Appendix I: SRH-2D Model Stability and Continuity

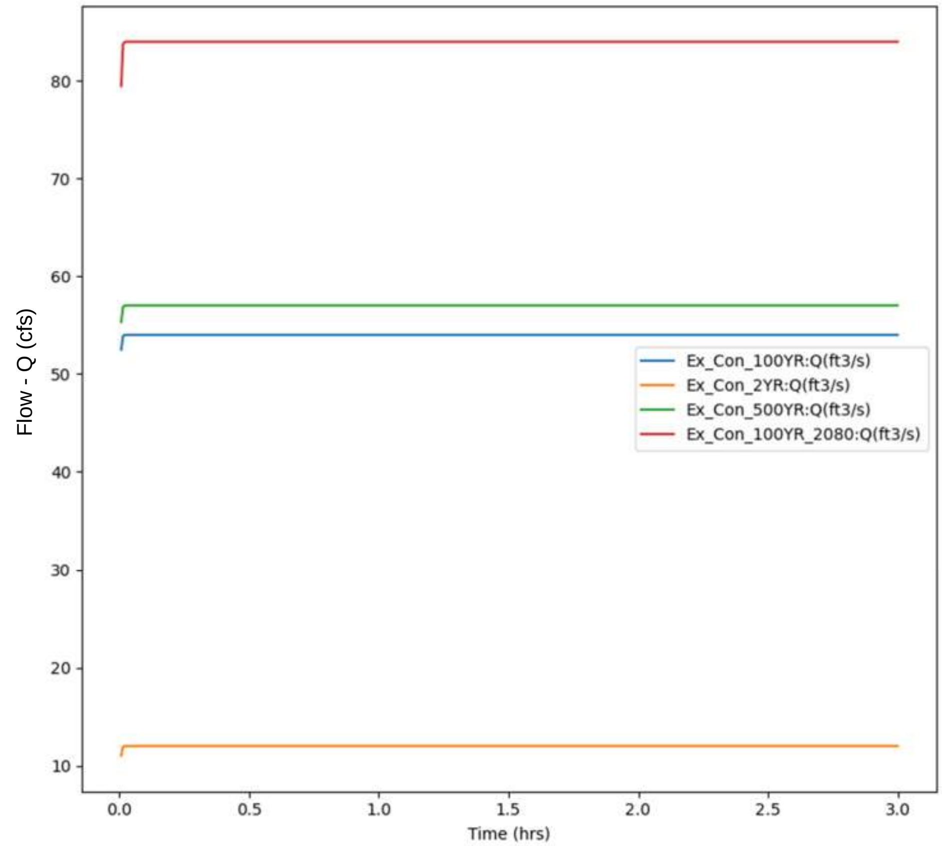
Existing Condition — Monitor Line Locations



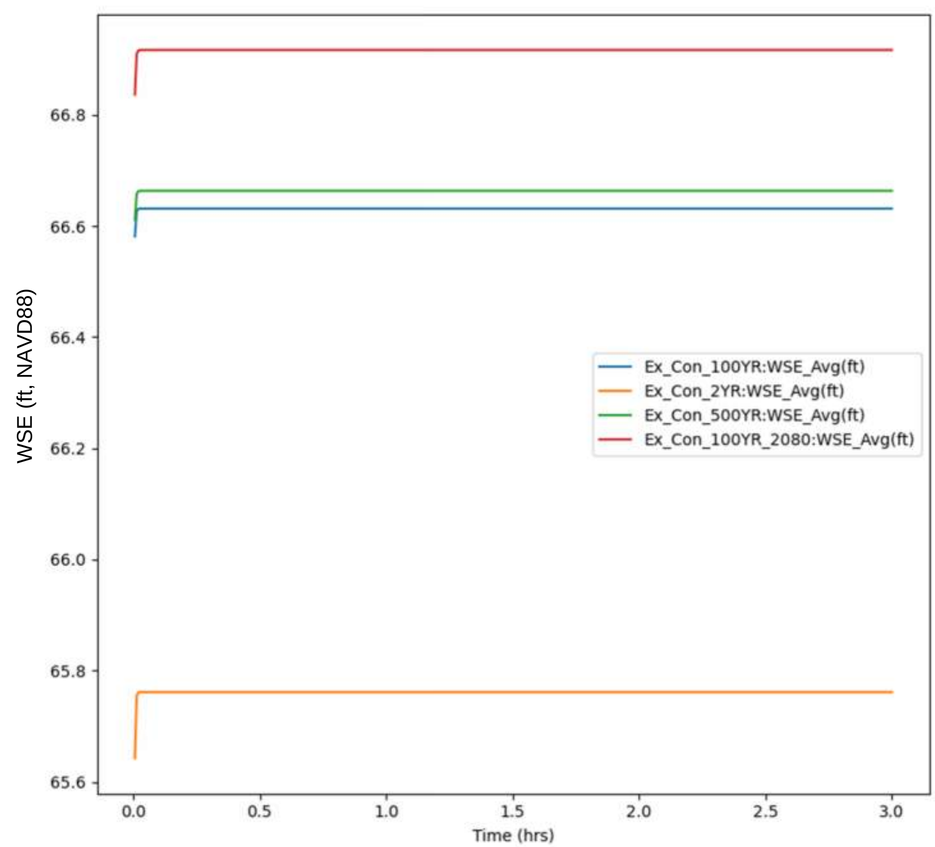
Natural Condition and Proposed Condition —Monitor Line Locations



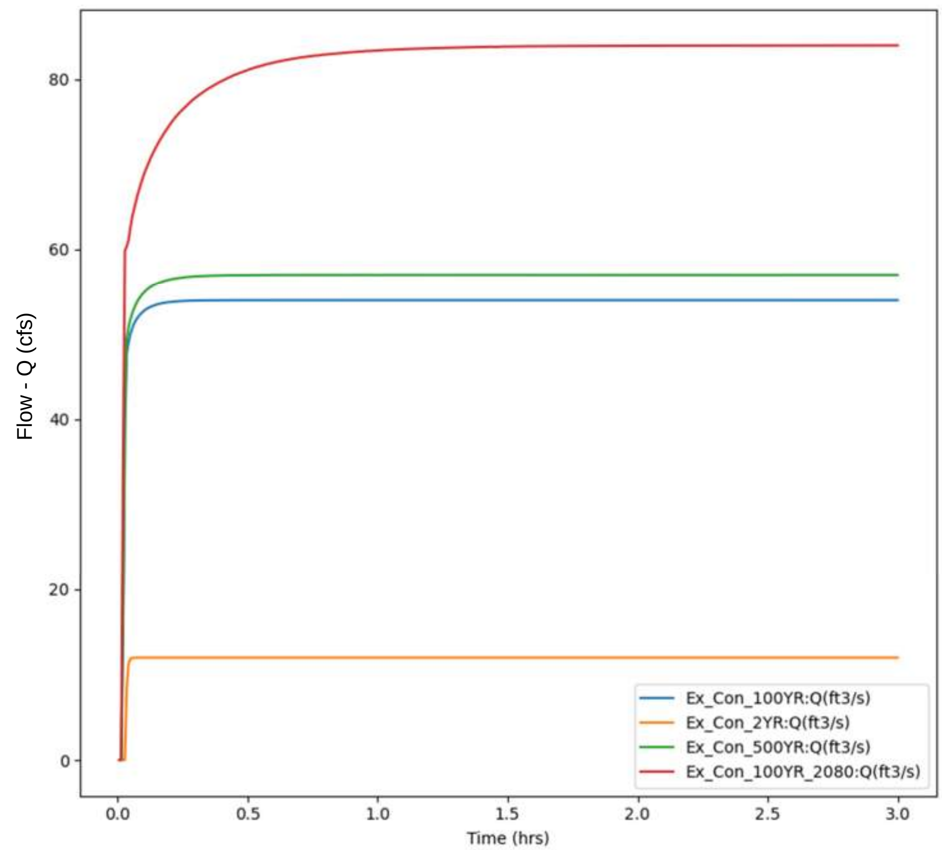
Existing Condition — Monitor Line 1 Flow vs. Time Plot



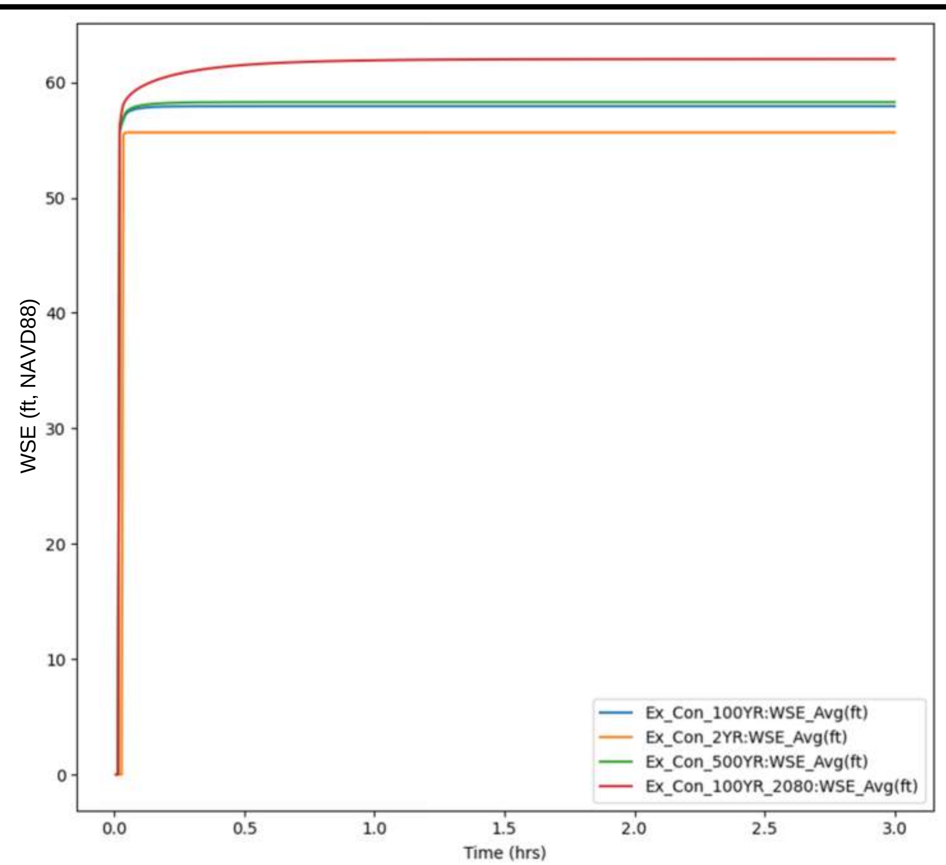
Existing Condition —Monitor Line 1 WSE vs. Time Plot



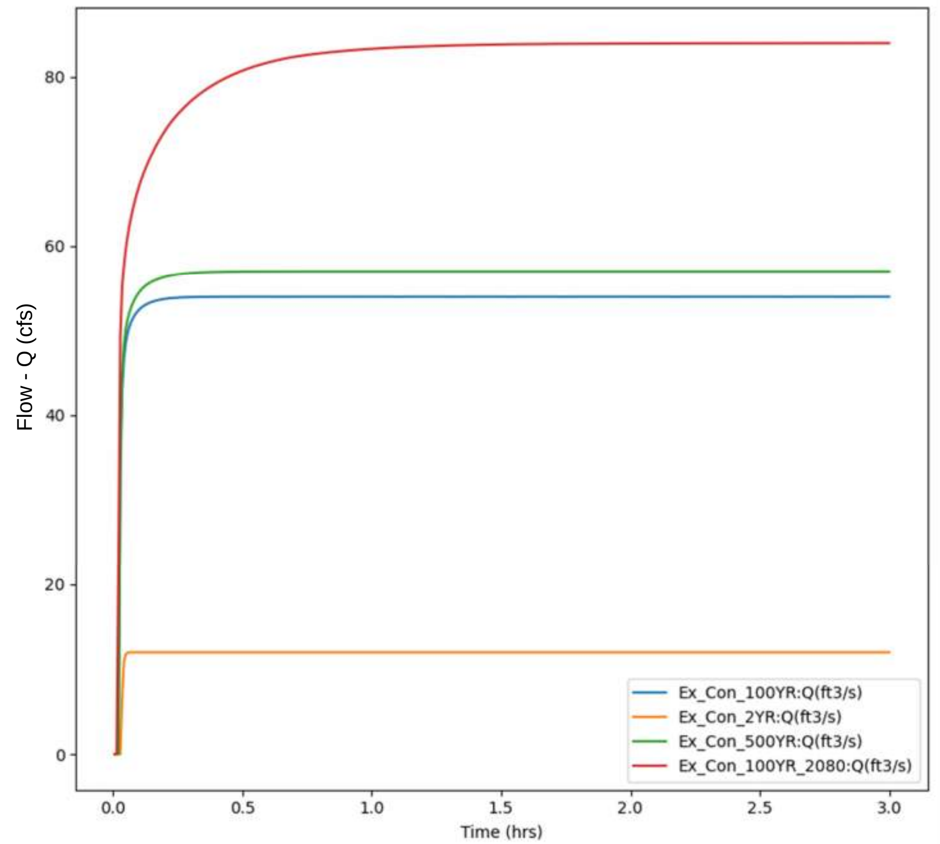
Existing Condition — Monitor Line 2 Flow vs. Time Plot



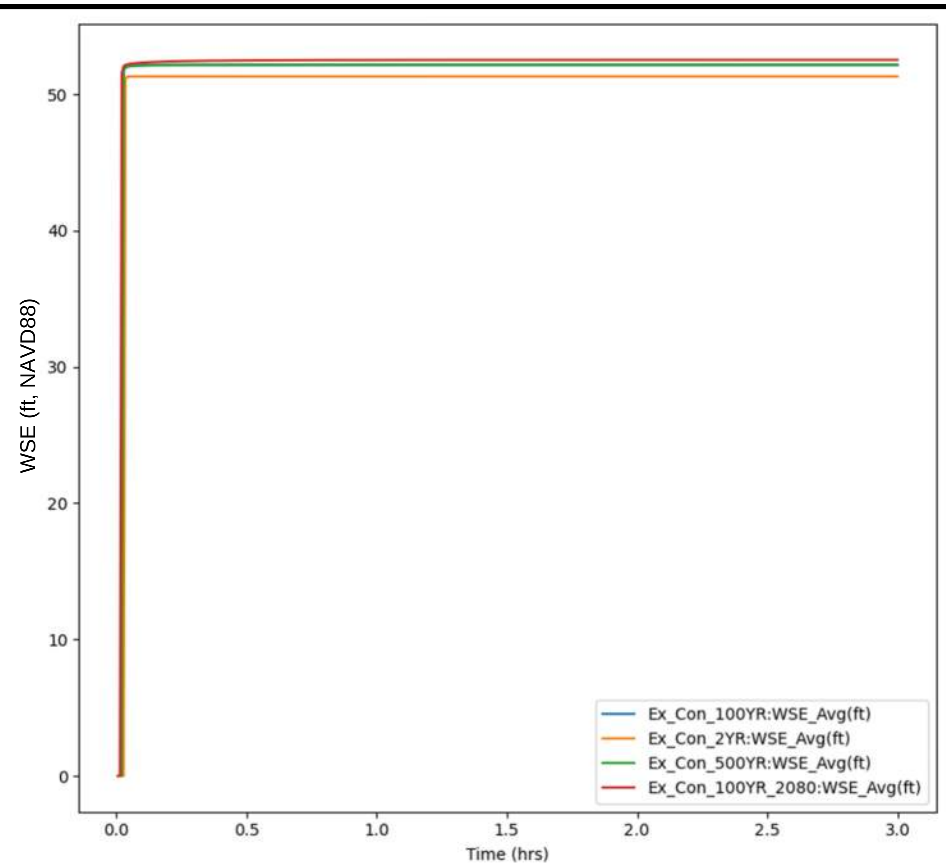
Existing Condition —Monitor Line 2 WSE vs. Time Plot



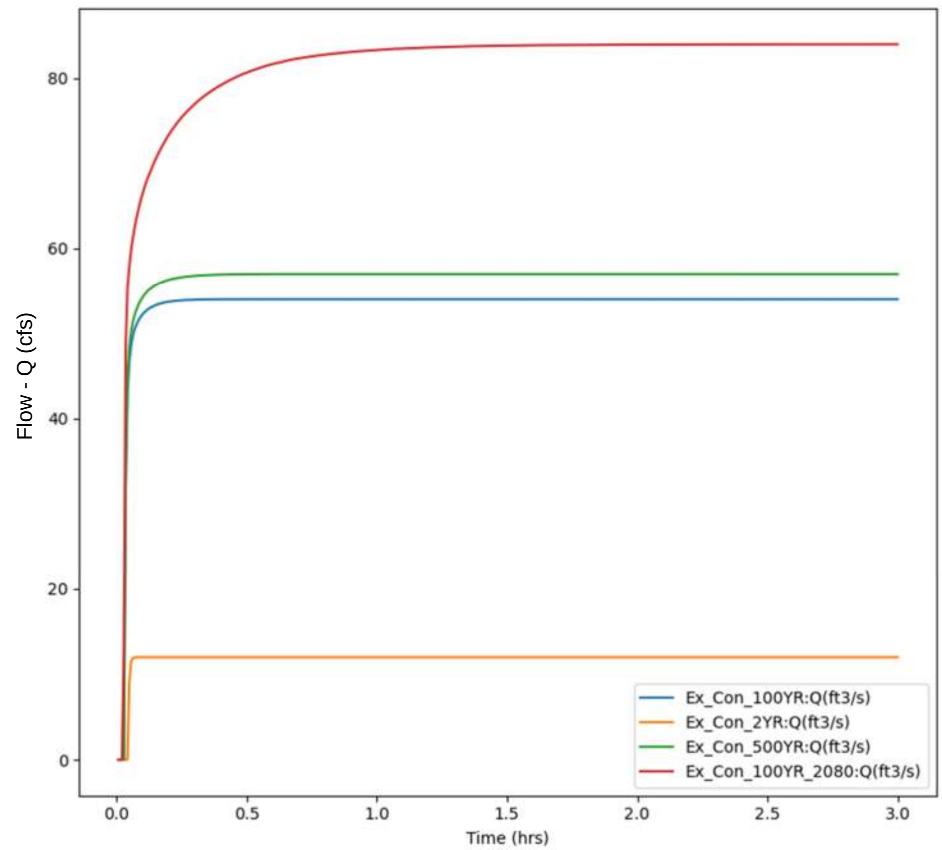
Existing Condition — Monitor Line 3 Flow vs. Time Plot



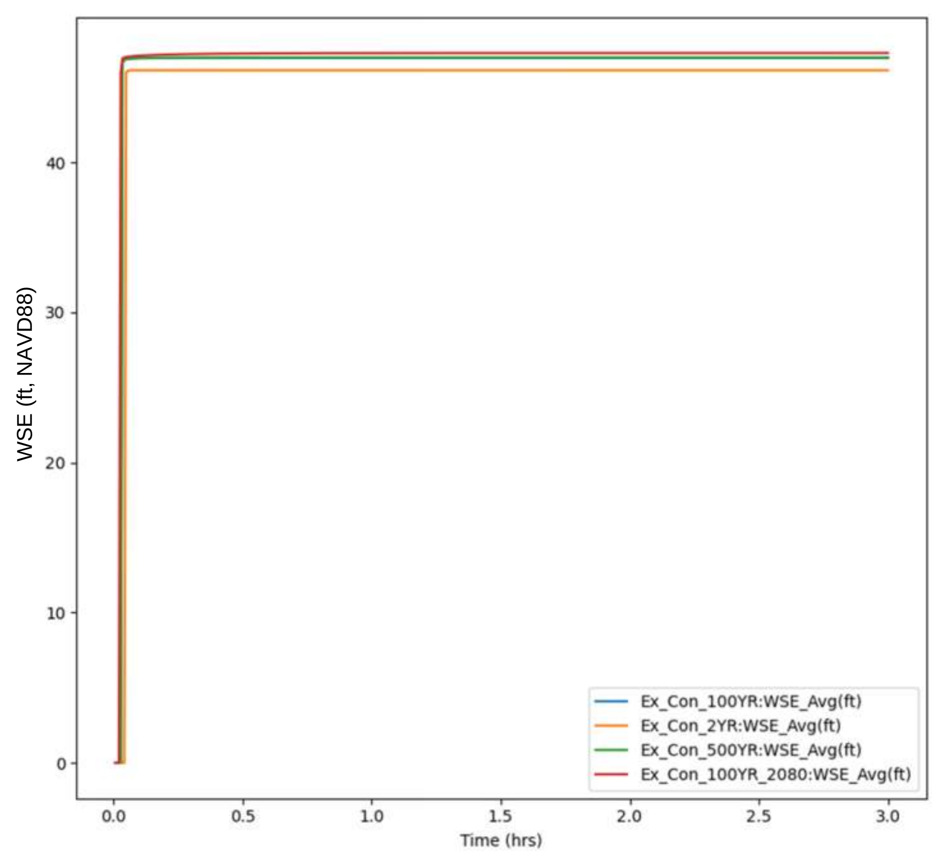
Existing Condition —Monitor Line 3 WSE vs. Time Plot



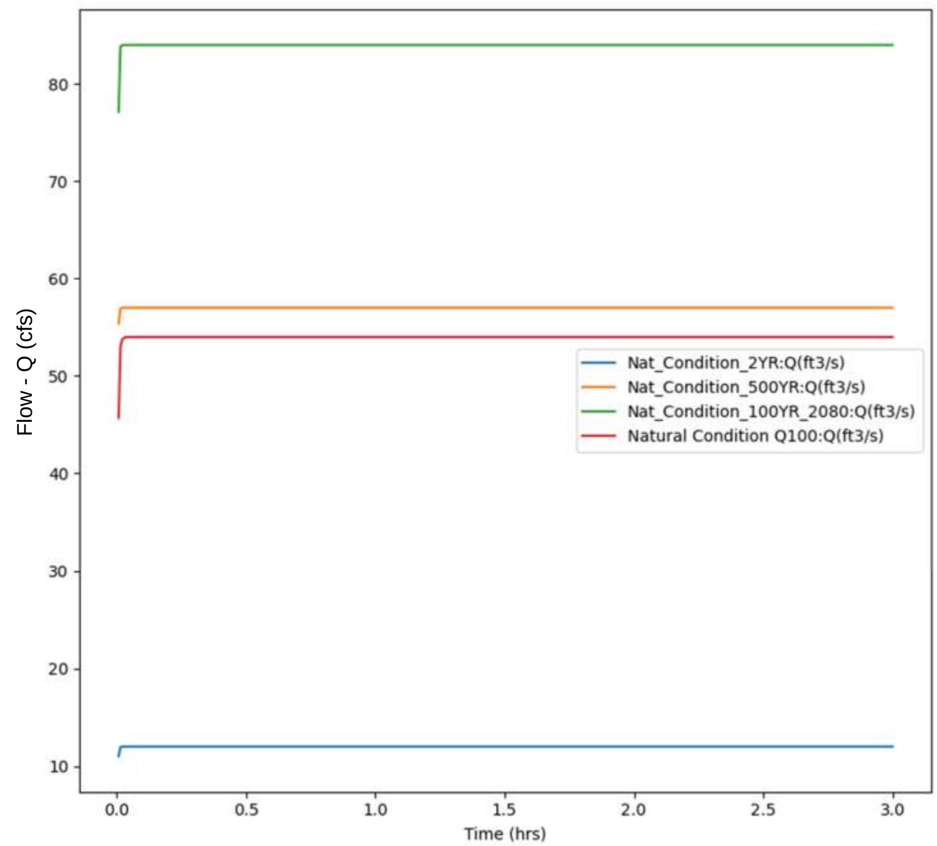
Existing Condition — Monitor Line 4 Flow vs. Time Plot



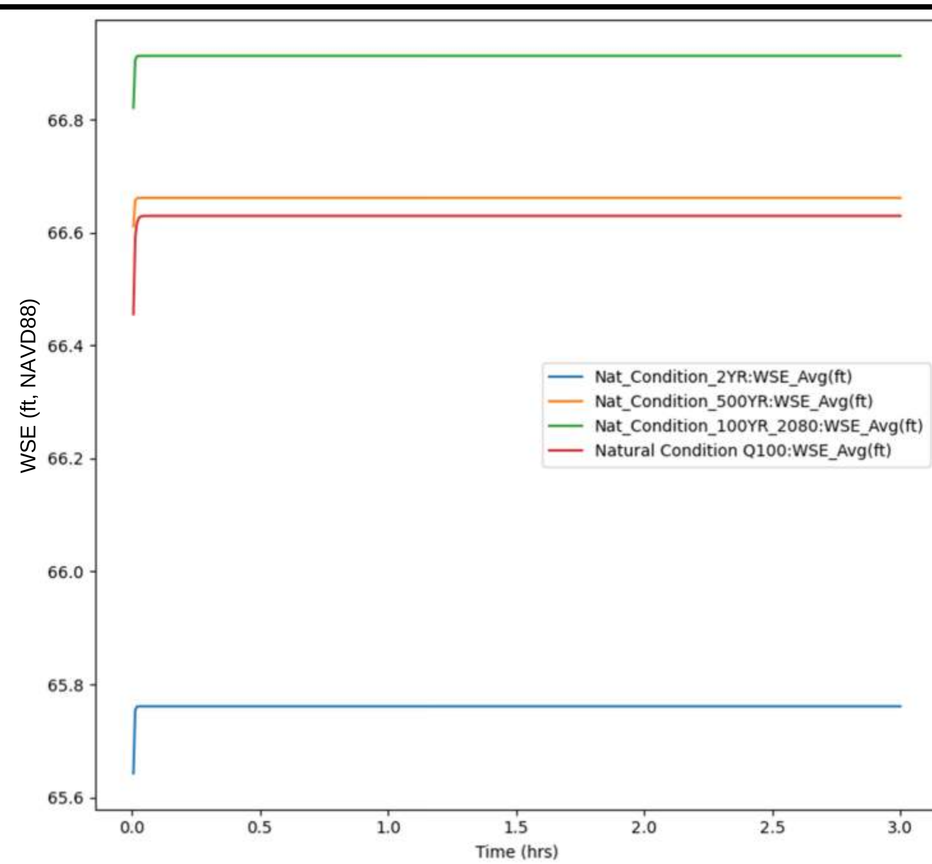
Existing Condition —Monitor Line 4 WSE vs. Time Plot



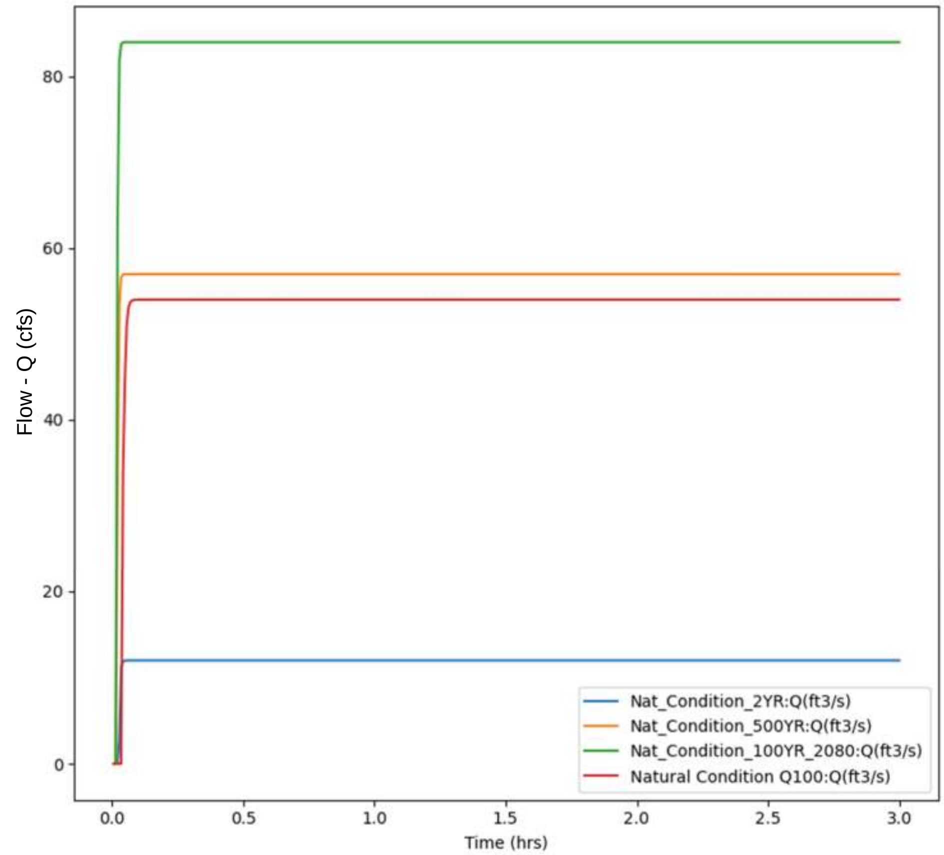
Natural Condition — Monitor Line 1 Flow vs. Time Plot



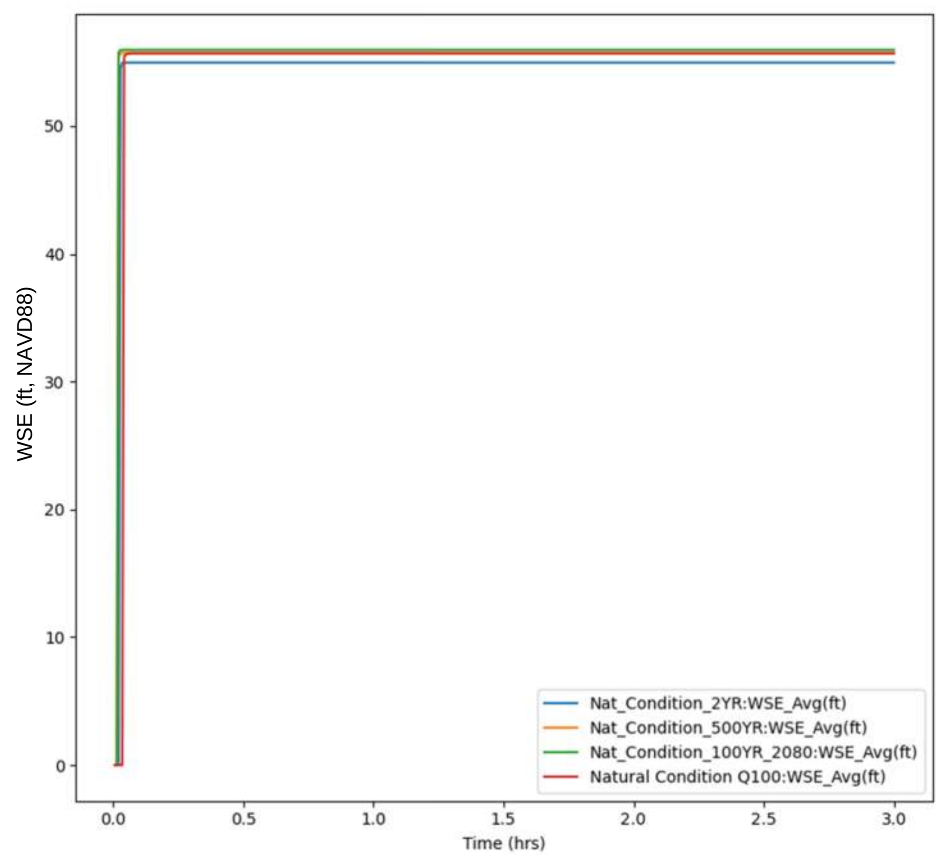
Natural Condition —Monitor Line 1 WSE vs. Time Plot



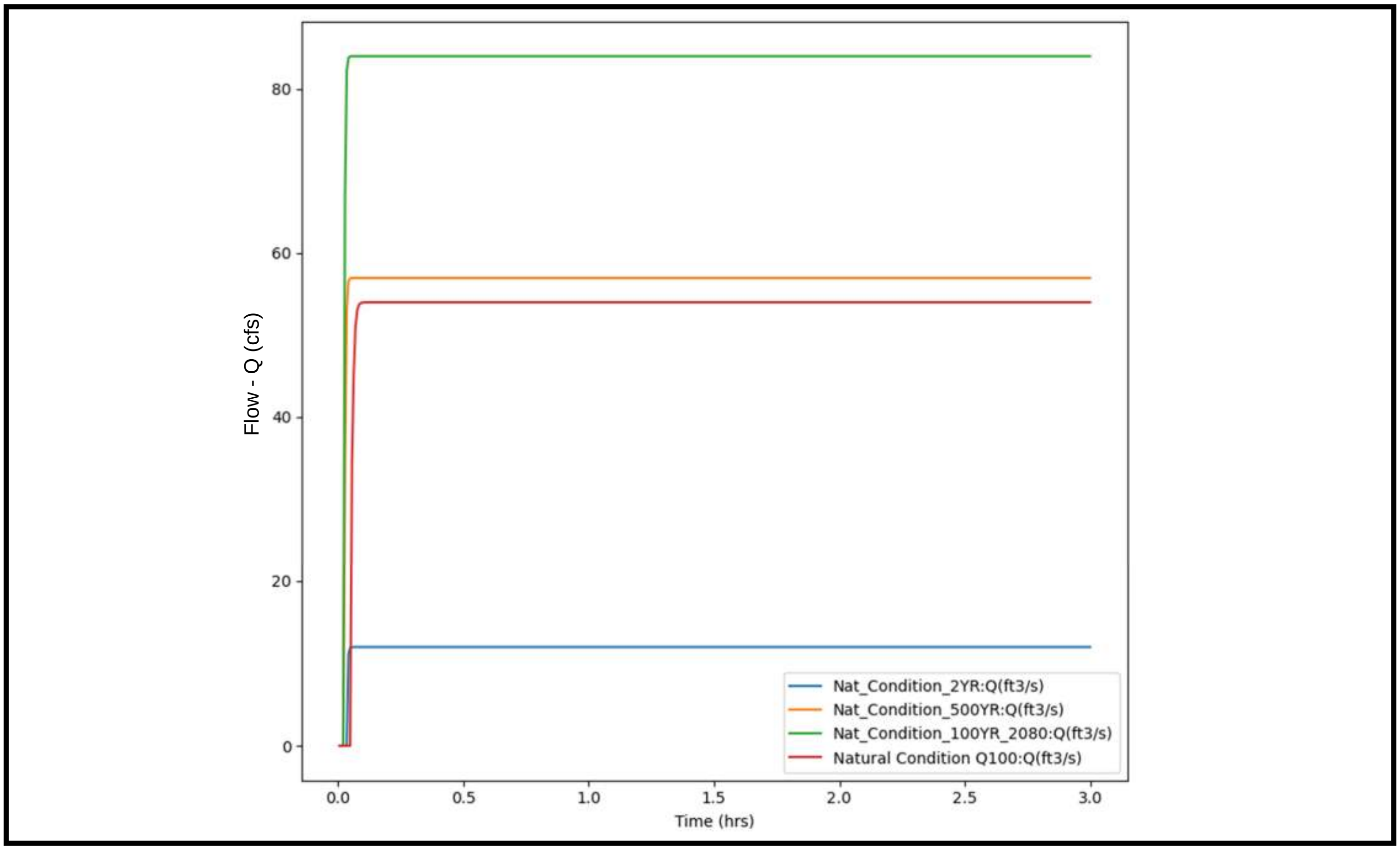
Natural Condition — Monitor Line 2 Flow vs. Time Plot



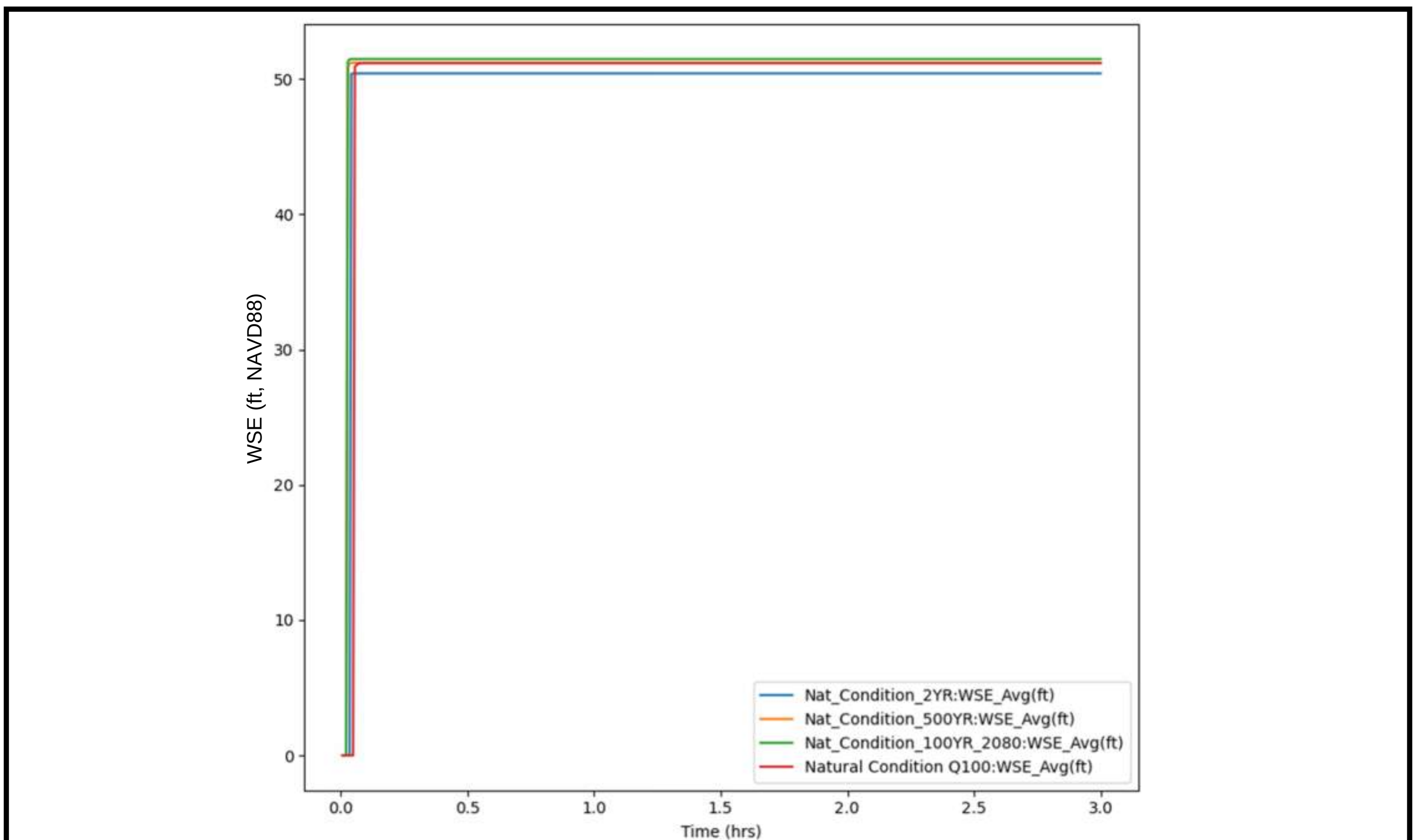
Natural Condition —Monitor Line 2 WSE vs. Time Plot



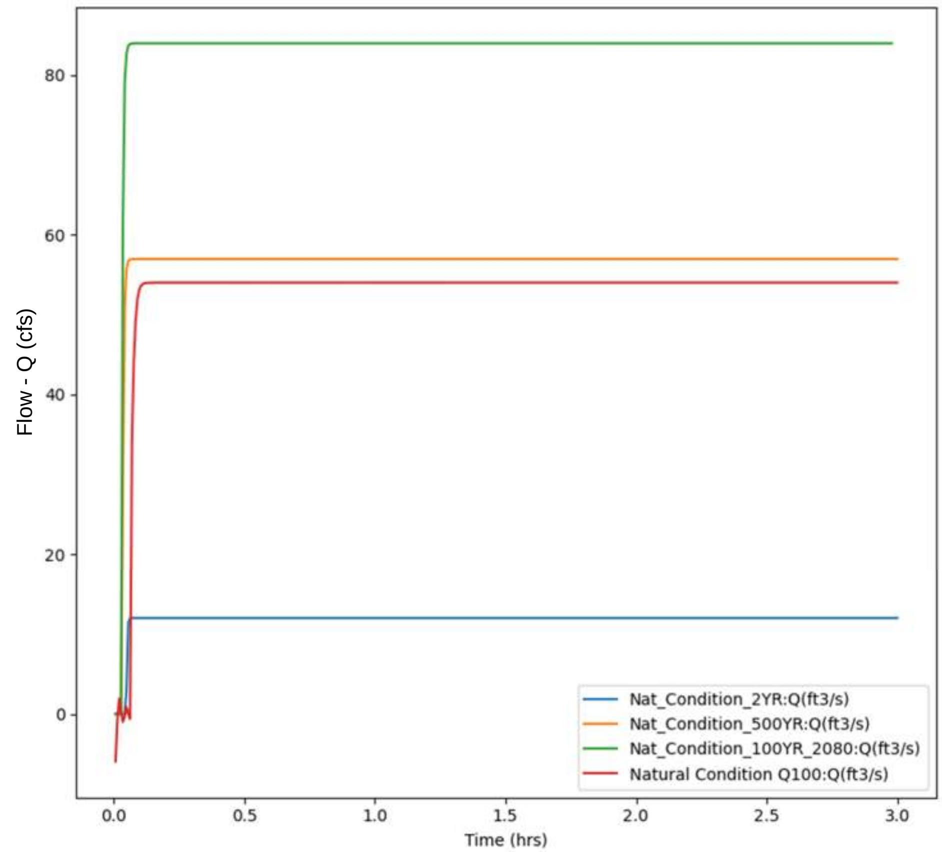
Natural Condition — Monitor Line 3 Flow vs. Time Plot



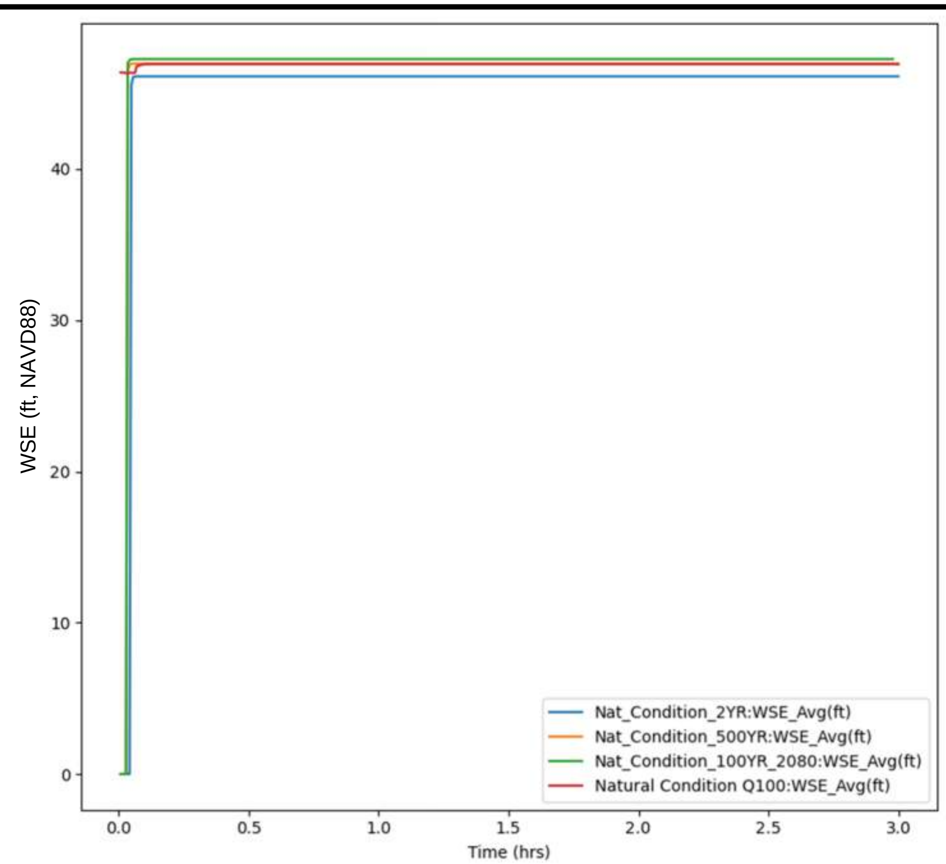
Natural Condition —Monitor Line 3 WSE vs. Time Plot



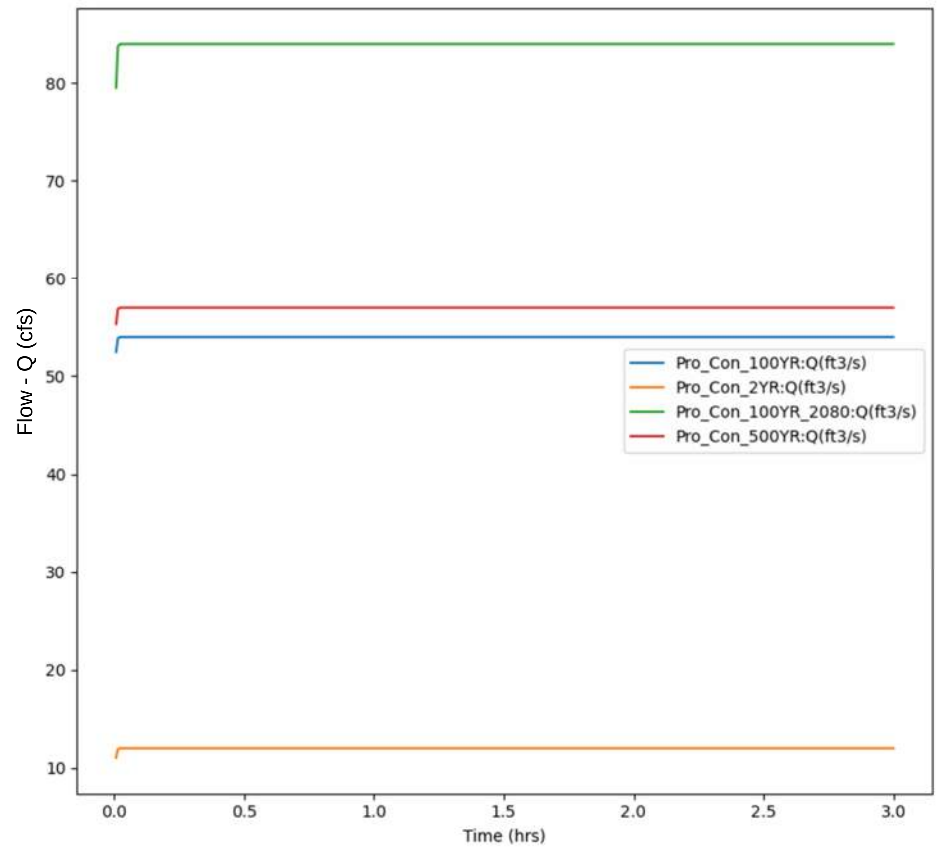
Natural Condition — Monitor Line 4 Flow vs. Time Plot



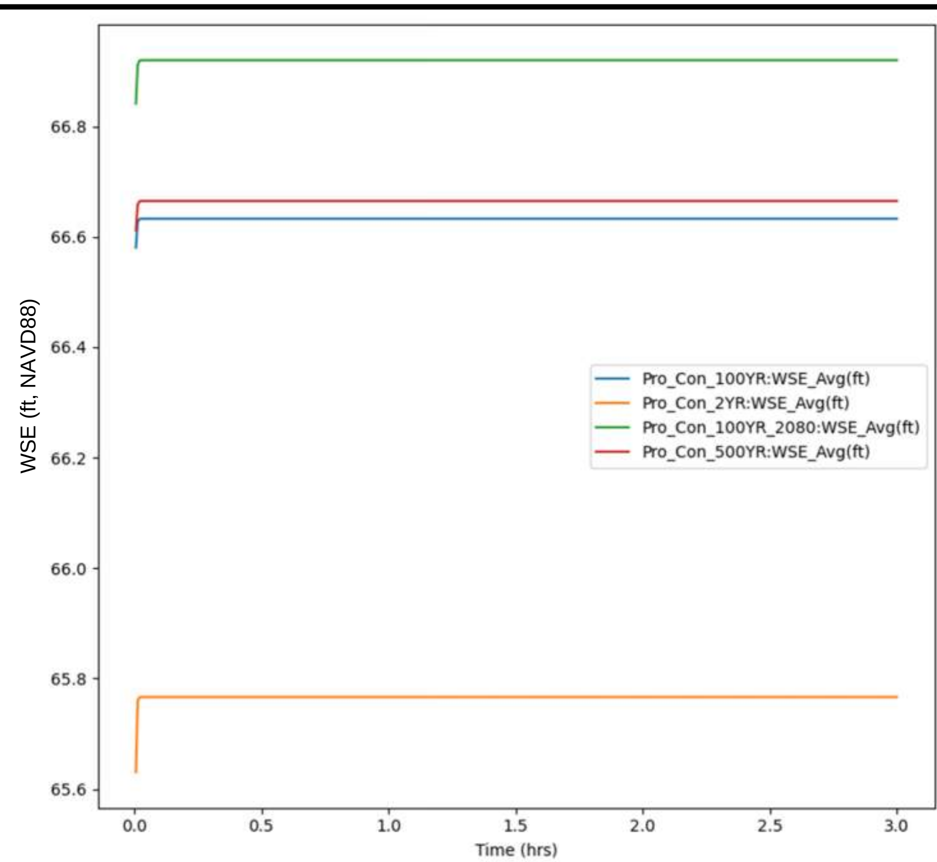
Natural Condition —Monitor Line 4 WSE vs. Time Plot



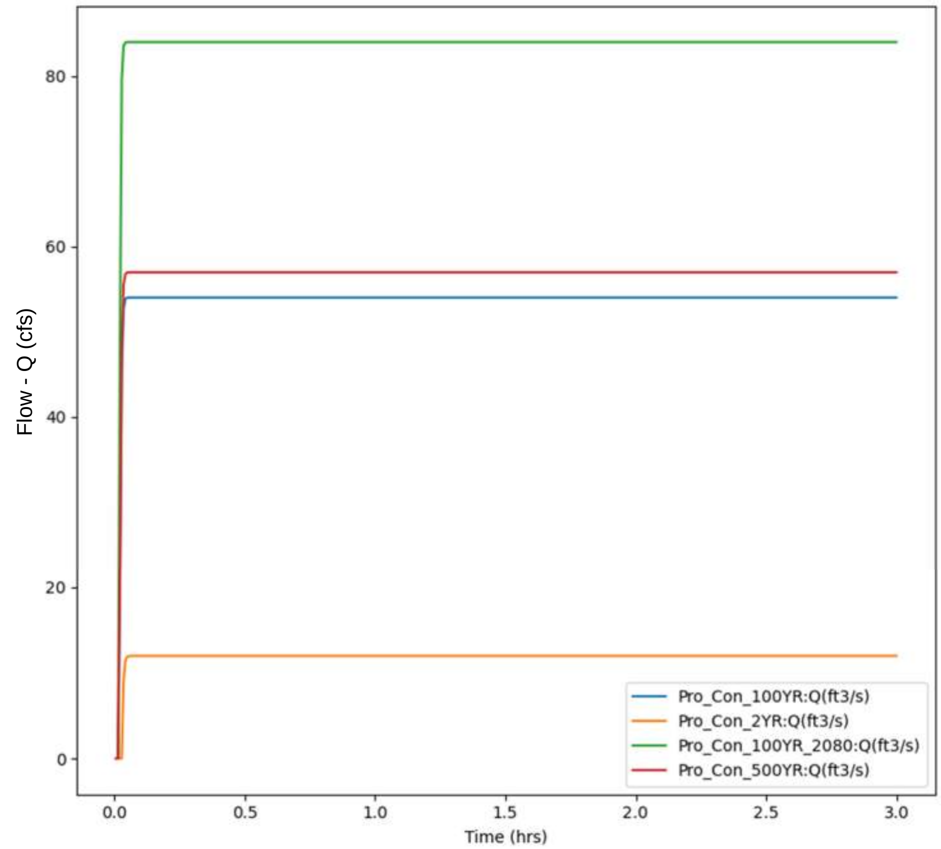
Proposed Condition — Monitor Line 1 Flow vs. Time Plot



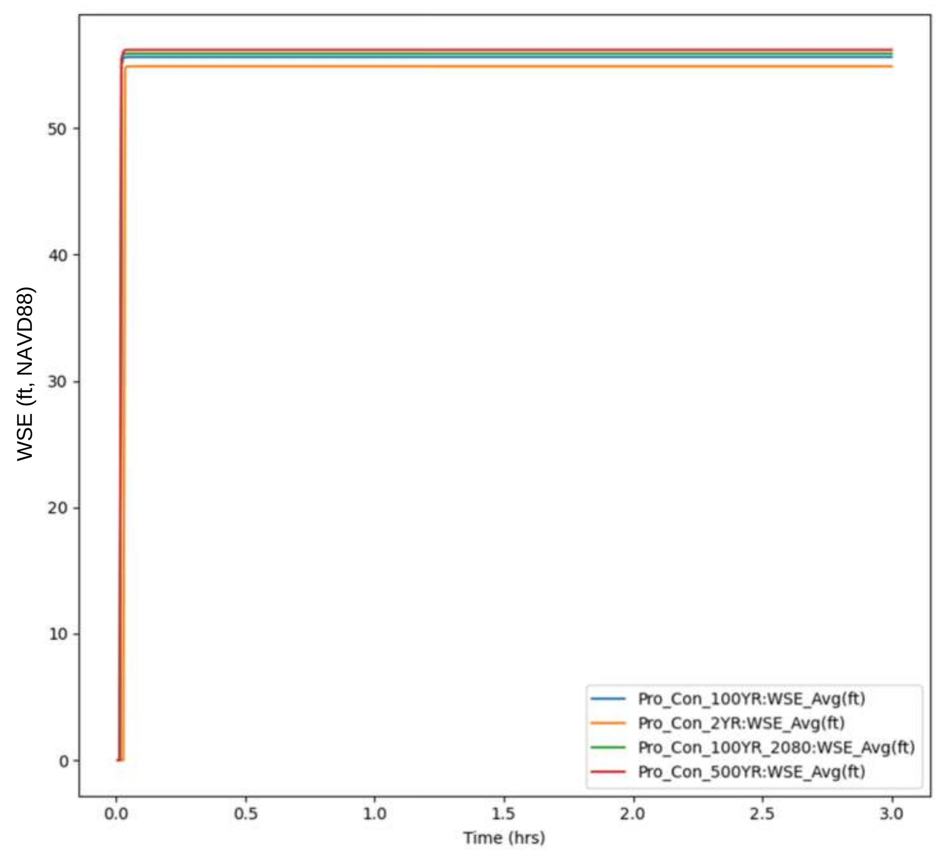
Proposed Condition —Monitor Line 1 WSE vs. Time Plot



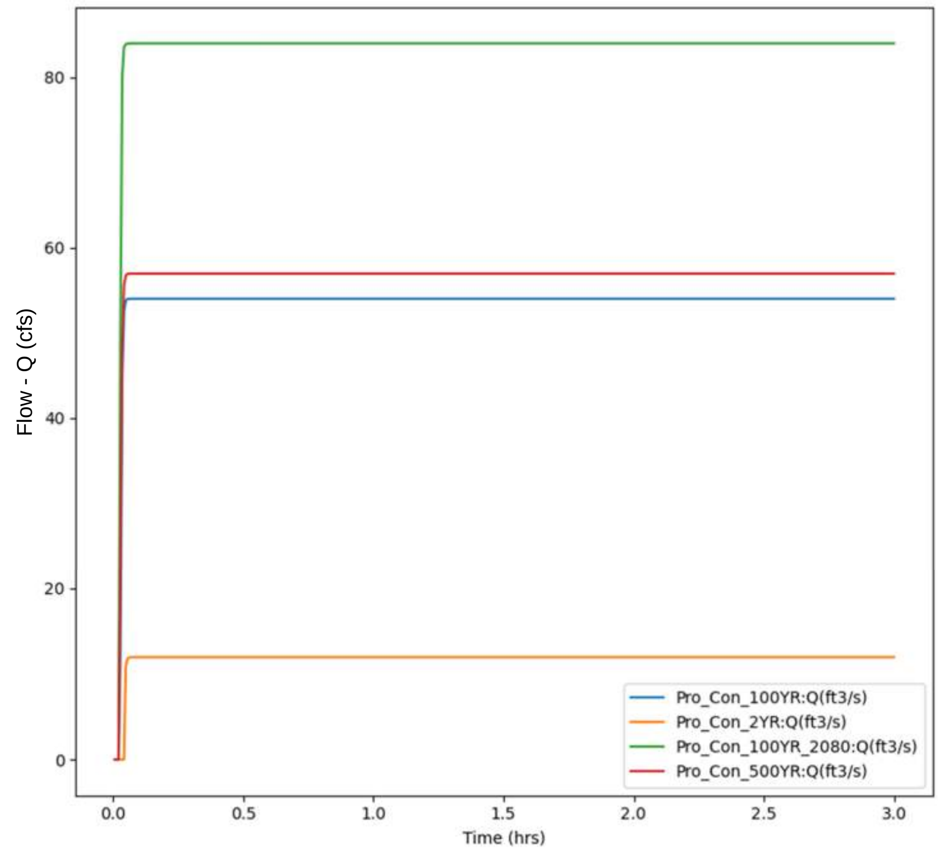
Proposed Condition — Monitor Line 2 Flow vs. Time Plot



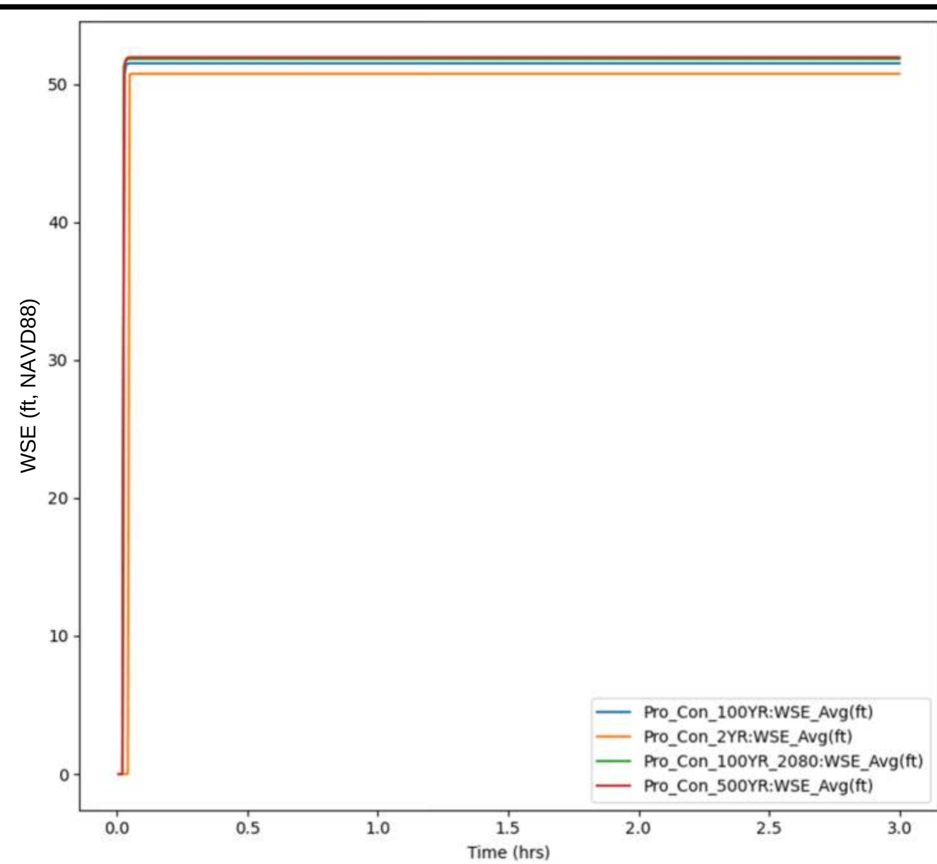
Proposed Condition —Monitor Line 2 WSE vs. Time Plot



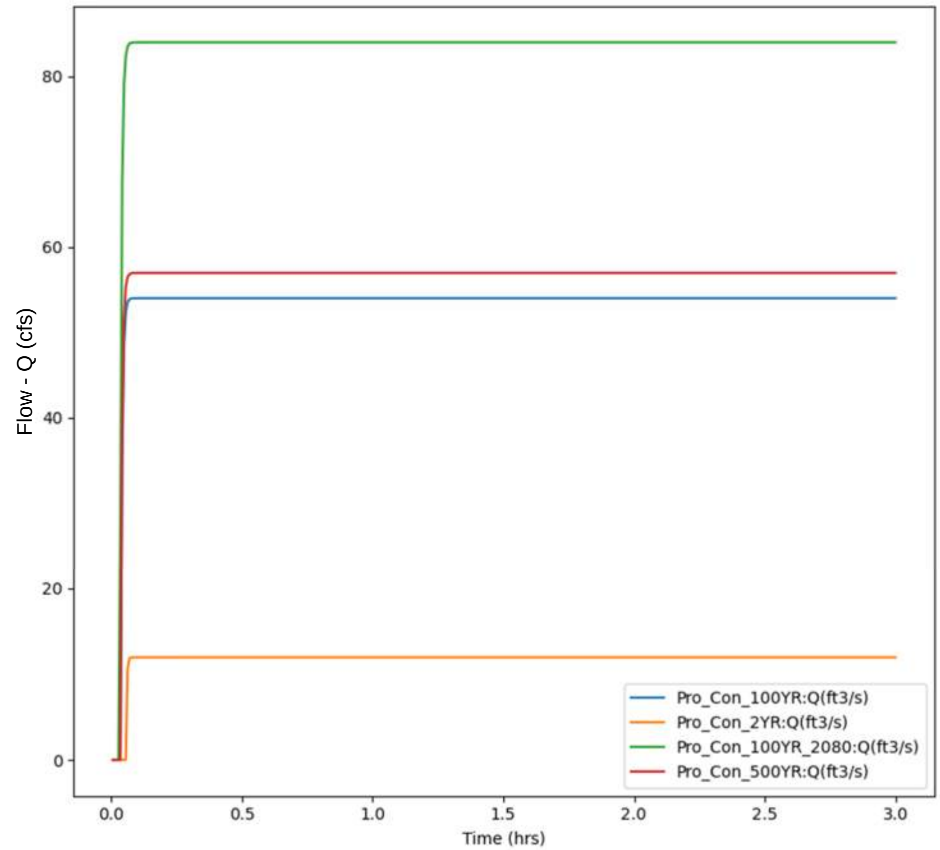
Proposed Condition — Monitor Line 3 Flow vs. Time Plot



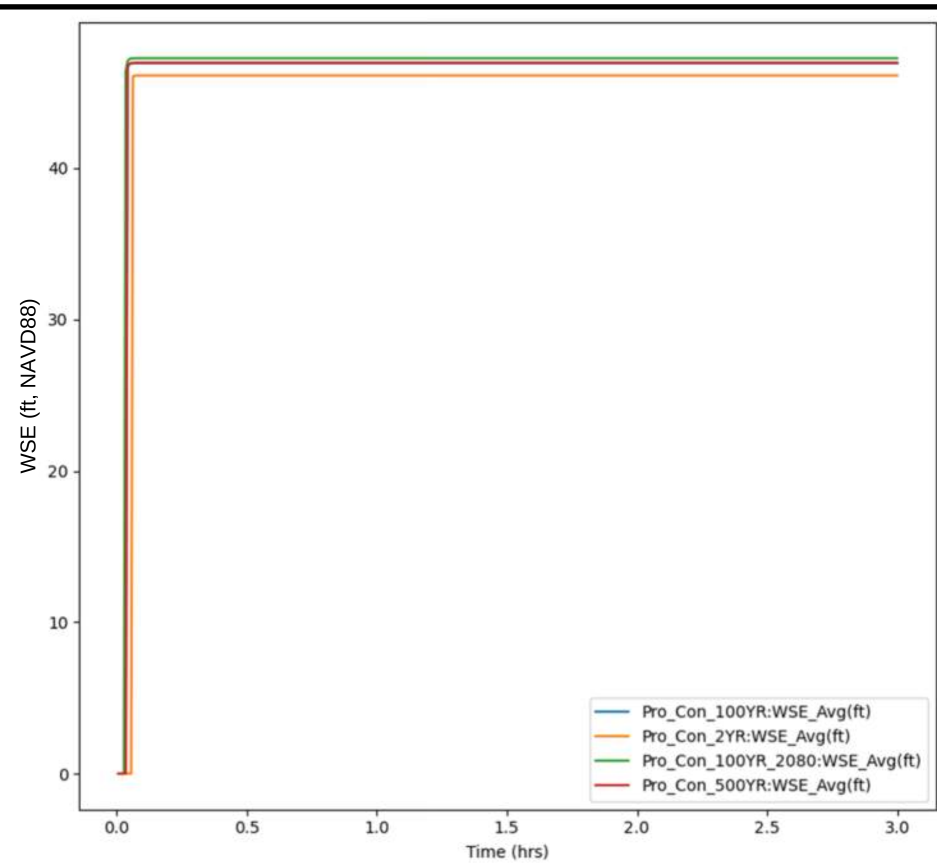
Proposed Condition —Monitor Line 3 WSE vs. Time Plot



Proposed Condition — Monitor Line 4 Flow vs. Time Plot



Proposed Condition —Monitor Line 4 WSE vs. Time Plot

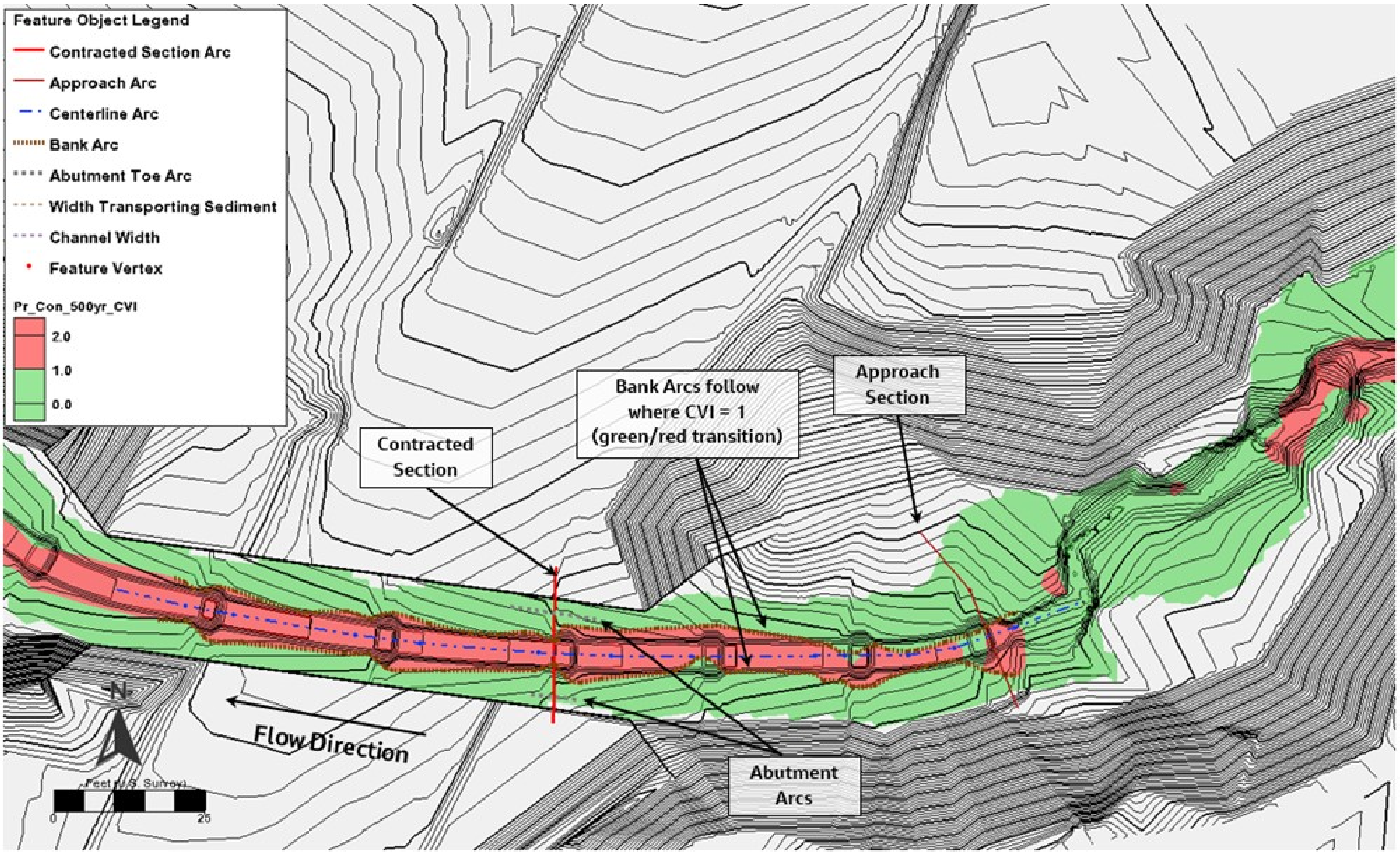


Appendix J: Reach Assessment

There is no reach assessment for UNT to Kinman Creek at SR 3 MP 57.23

Appendix K: Scour Calculations

Bridge Scour Coverage, 2080 100yr, Approach Arc Between Crossings



2 year flow, Main Channel Contraction Scour

Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	1.14	ft	
D50	15.240000	mm	0.2 mm is the lower limit for …
Average Velocity Upstream	2.28	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s…	4.20	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	9.60	cfs	
Bottom Width in Contracted Section	4.05	ft	Width should exclude pier wi…
Depth Prior to Scour in Contracted Section	1.09	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	°F	
Slope of Energy Grade Line at Approach Section	0.005374	ft/ft	
Discharge in Contracted Section	9.60	cfs	
Discharge Upstream that is Transporting Sediment	8.28	cfs	
Width in Contracted Section	4.05	ft	Remove widths occupied by …
Width Upstream that is Transporting Sediment	3.20	ft	
Depth Prior to Scour in Contracted Section	1.09	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b…	19.050000	mm	
Average Depth in Contracted Section after Scour	0.57	ft	
Scour Depth	-0.52	ft	Negative values imply 'zero' …
Results of Live Bed Method			
k1	0.590000		
Shear Velocity	0.44	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	1.12	ft	
Scour Depth	0.03	ft	Negative values imply 'zero' …
Shear Applied to Bed by Live-Bed Scour	0.0557	lb/ft^2	
Shear Required for Movement of D50 Particle	0.2001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.52	ft	Negative values imply 'zero' …

2 year flow, Left Abutment Scour

Abutment Scour

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutment		
Unit Discharge, Upstream in Main Channel (q1)	2.59	cfs/ft	
Unit Discharge in Constricted Area (q2)	2.37	cfs/ft	
D50	15.240000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	1.14	ft	
Define Shear Stress of Floodplain			
Flow Depth prior to Scour	1.18	ft	Depth at Abutment Toe
Results			
q2 / q1	0.92		
Average Velocity Upstream	2.28	ft/s	
Critical Velocity above which Bed Material of Size D and Sm...	4.20	ft/s	
Scour Condition	Clear Water		
Scour Condition	a (Main Channel)		
Amplification Factor	1.20		
Flow Depth including Contraction Scour	0.62	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	0.75	ft	Including the long-term scour de...
Scour Hole Depth	-0.43	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...

100 year flow, Main Channel Contraction Scour

Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	1.06	ft	
D50	15.240000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	1.28	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	4.16	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	15.65	cfs	
Bottom Width in Contracted Section	3.96	ft	Width should exclude pier wi...
Depth Prior to Scour in Contracted Section	1.91	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	ºF	
Slope of Energy Grade Line at Approach Section	0.017546	ft/ft	
Discharge in Contracted Section	15.65	cfs	
Discharge Upstream that is Transporting Sediment	11.35	cfs	
Width in Contracted Section	3.96	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	8.31	ft	
Depth Prior to Scour in Contracted Section	1.91	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	19.050000	mm	
Average Depth in Contracted Section after Scour	0.89	ft	
Scour Depth	-1.02	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.590000		
Shear Velocity	0.78	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	2.17	ft	
Scour Depth	0.26	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	0.0517	lb/ft^2	
Shear Required for Movement of D50 Particle	0.2001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-1.02	ft	Negative values imply 'zero' ...

100 year flow, Left Abutment Scour

Abutment Scour

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutment		
Unit Discharge, Upstream in Main Channel (q1)	1.37	cfs/ft	
Unit Discharge in Constricted Area (q2)	3.95	cfs/ft	
D50	15.240000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	1.06	ft	
Define Shear Stress of Floodplain			
Flow Depth prior to Scour	2.02	ft	Depth at Abutment Toe
Results			
q2 / q1	2.89		
Average Velocity Upstream	1.29	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	4.16	ft/s	
Scour Condition	Clear Water		
Scour Condition	a (Main Channel)		
Amplification Factor	1.11		
Flow Depth including Contraction Scour	0.97	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	1.07	ft	Including the long-term scour de...
Scour Hole Depth	-0.95	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...

500 year flow, Main Channel Contraction Scour

Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	1.09	ft	
D50	15.240000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	5.06	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	4.18	ft/s	
Contraction Scour Condition	Live Bed		
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	ºF	
Slope of Energy Grade Line at Approach Section	0.018927	ft/ft	
Discharge in Contracted Section	35.41	cfs	
Discharge Upstream that is Transporting Sediment	45.86	cfs	
Width in Contracted Section	3.97	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	8.31	ft	
Depth Prior to Scour in Contracted Section	1.94	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	19.050000	mm	
Average Depth in Contracted Section after Scour	1.79	ft	
Scour Depth	-0.15	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.590000		
Shear Velocity	0.82	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	1.35	ft	
Scour Depth	-0.59	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	0.5790	lb/ft^2	
Shear Required for Movement of D50 Particle	0.2001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.59	ft	Negative values imply 'zero' ...

500 year flow, Left Abutment Scour

Abutment Scour

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutment		
Unit Discharge, Upstream in Main Channel (q1)	5.52	cfs/ft	
Unit Discharge in Constricted Area (q2)	8.94	cfs/ft	
D50	15.240000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	1.09	ft	
Define Shear Stress of Floodplain	☐		
Flow Depth prior to Scour	1.81	ft	Depth at Abutment Toe
Results			
q2 / q1	1.62		
Average Velocity Upstream	5.06	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	4.18	ft/s	
Scour Condition	Live Bed		
Scour Condition	a (Main Channel)		
Amplification Factor	1.49		
Flow Depth including Contraction Scour	1.65	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	2.47	ft	Including the long-term scour de...
Scour Hole Depth	0.66	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...
Scour Hole Bottom Width	0.00	ft	
Scour Hole Top Width	0.68	ft	

2080 100 year flow, Main Channel Contraction Scour

Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	1.31	ft	
D50	15.240000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	5.33	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	4.31	ft/s	
Contraction Scour Condition	Live Bed		
Live Bed & Clear Water Input Parameters			
Temperature of Water	50.00	°F	
Slope of Energy Grade Line at Approach Section	0.034333	ft/ft	
Discharge in Contracted Section	44.85	cfs	
Discharge Upstream that is Transporting Sediment	58.17	cfs	
Width in Contracted Section	3.95	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	8.31	ft	
Depth Prior to Scour in Contracted Section	2.20	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	19.050000	mm	
Average Depth in Contracted Section after Scour	2.20	ft	
Scour Depth	-0.00	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	1.20	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	1.69	ft	
Scour Depth	-0.51	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	0.6457	lb/ft^2	
Shear Required for Movement of D50 Particle	0.2001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.51	ft	Negative values imply 'zero' ...

2080 100 year flow, Left Abutment Scour

Abutment Scour

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutment		
Unit Discharge, Upstream in Main Channel (q1)	7.00	cfs/ft	
Unit Discharge in Constricted Area (q2)	11.34	cfs/ft	
D50	15.240000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	1.31	ft	
Define Shear Stress of Floodplain			
Flow Depth prior to Scour	2.27	ft	Depth at Abutment Toe
Results			
q2 / q1	1.62		
Average Velocity Upstream	5.33	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	4.31	ft/s	
Scour Condition	Live Bed		
Scour Condition	a (Main Channel)		
Amplification Factor	1.49		
Flow Depth including Contraction Scour	1.99	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	2.97	ft	Including the long-term scour de...
Scour Hole Depth	0.70	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...
Scour Hole Bottom Width	0.00	ft	
Scour Hole Top Width	0.72	ft	

Appendix L: Floodplain Analysis *(FHD ONLY)*

Floodplain Analysis will be provided at the FHD for UNT to Kinman Creek at SR 3 MP 57.23.

Appendix M: Scour Countermeasure Calculations (FHD ONLY)

*Scour countermeasure calculations will be provided at the FHD for UNT to Kinman Creek at SR 3 MP 57.2*3.

Appendix N: Hydrology

Attachment 1. MGS Flood Input/Output Summary

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.57
Program License Number: 200710001
Project Simulation Performed on: 02/25/2022 11:08 AM
Report Generation Date: 02/25/2022 11:13 AM

Input File Name: MGS991242.fld
Project Name: 991242
Analysis Title: PHD WSDOT
Comments:

PRECIPITATION INPUT

Computational Time Step (Minutes): 15

Extended Precipitation Time Series Selected
Climatic Region Number: 2

Full Period of Record Available used for Routing
Precipitation Station : 95003605 Puget West 36 in_5min 10/01/1939-10/01/2097
Evaporation Station : 951036 Puget West 36 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 3
HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) ***************

********************** WATERSHED DEFINITION ***********************

Predevelopment/Post Development Tributary Area Summary

	Predeveloped	Post Developed
Total Subbasin Area (acres)	566.500	1.000
Area of Links that Include Precip/Evap (acres)	0.000	0.000
Total (acres)	566.500	1.000

----------------------SCENARIO: MGSFLOOD_15MIN_3SUBBASIN
Number of Subbasins: 3

---------- Subbasin : 991242A ----------

	-------Area (Acres) --------
Till Forest	269.380
Till Grass	26.240
Outwash Forest	16.360
Wetland	34.550

Subbasin Total 346.530

---------- Subbasin : 991242B ----------

	-------Area (Acres) --------
Till Forest	34.570
Till Pasture	0.890
Till Grass	6.690
Outwash Forest	3.560
Outwash Pasture	0.130
Outwash Grass	5.720
Impervious	2.020
Subbasin Total	53.580

---------- Subbasin : 991242C ----------

	-------Area (Acres) --------
Till Forest	54.580
Till Grass	38.960
Outwash Forest	68.260
Outwash Grass	4.280
Impervious	0.310
Subbasin Total	166.390

---------------------SCENARIO: POSTDEVELOPED

Number of Subbasins: 1

---------- Subbasin : All ----------

	-------Area (Acres) --------
Till Forest	1.000
Subbasin Total	1.000

**************************** LINK DATA *******************************

----------------------SCENARIO: MGSFLOOD_15MIN_3SUBBASIN

Number of Links: 3

--

Link Name: FS_location

Link Type: Open Channel

Downstream Link: None

----------Left Overbank

Upper Sideslope (z) : 0.200

Upper Width (ft) : 51.000

Middle Sideslope (z) : 0.300

Middle Width (ft) : 30.000

Mannings n : 0.035

----------Main Channel
Lower Sideslope Left (z) : 0.400
Lower Width Left (ft) : 96.000
Lower Sideslope Right (z) : 0.300
Lower Width Right (ft) : 51.000
Mannings n : 0.024
Base Width (ft) : 51.0
Elevation (ft) : 137.52
Channel Slope (ft/ft) : 0.040
Channel Length (ft) : 2847.0

----------Right Overbank
Upper Sideslope (z) : 0.400
Upper Width (ft) : 51.000
Middle Sideslope (z) : 0.200
Middle Width (ft) : 48.000
Mannings n : 0.035

Hydraulic Conductivity (in/hr) : 0.0
Massmann Regression Used to Estimate Hydralic Gradient
Depth to Water Table (ft) : 100.0
Bio-Fouling Potential : Low
Maintenance : Average or Better

--
Link Name: OC_1
Link Type: Open Channel
Downstream Link Name: FS_location

----------Left Overbank
Upper Sideslope (z) : 0.200
Upper Width (ft) : 74.000
Middle Sideslope (z) : 0.200
Middle Width (ft) : 108.000
Mannings n : 0.035

----------Main Channel
Lower Sideslope Left (z) : 0.300
Lower Width Left (ft) : 113.000
Lower Sideslope Right (z) : 0.600
Lower Width Right (ft) : 48.000
Mannings n : 0.024
Base Width (ft) : 93.0
Elevation (ft) : 295.22
Channel Slope (ft/ft) : 0.040
Channel Length (ft) : 6783.0

----------Right Overbank
Upper Sideslope (z) : 0.200
Upper Width (ft) : 36.000
Middle Sideslope (z) : 0.500
Middle Width (ft) : 113.000
Mannings n : 0.035

Hydraulic Conductivity (in/hr)   : 0.0
Massmann Regression Used to Estimate Hydralic Gradient
Depth to Water Table (ft)   : 100.0
Bio-Fouling Potential   : Low
Maintenance   : Average or Better

--
Link Name: OC_2
Link Type: Open Channel
Downstream Link Name: FS_location

----------Left Overbank
Upper Sideslope (z)   : 0.200
Upper Width (ft)   : 27.000
Middle Sideslope (z)   : 0.400
Middle Width (ft)   : 48.000
Mannings n   : 0.035

----------Main Channel
Lower Sideslope Left (z)   : 0.400
Lower Width Left (ft)   : 69.000
Lower Sideslope Right (z)   : 0.200
Lower Width Right (ft)   : 45.000
Mannings n   : 0.024
Base Width (ft)   : 30.0
Elevation (ft)   : 215.91
Channel Slope (ft/ft)   : 0.040
Channel Length (ft)   : 4160.0

----------Right Overbank
Upper Sideslope (z)   : 0.500
Upper Width (ft)   : 12.000
Middle Sideslope (z)   : 0.600
Middle Width (ft)   : 45.000
Mannings n   : 0.035

Hydraulic Conductivity (in/hr)   : 0.0
Massmann Regression Used to Estimate Hydralic Gradient
Depth to Water Table (ft)   : 100.0
Bio-Fouling Potential   : Low
Maintenance   : Average or Better

**************************** LINK DATA ********************************

----------------------SCENARIO: POSTDEVELOPED
Number of Links: 0

**********************FLOOD FREQUENCY AND DURATION STATISTICS*******************

----------------------SCENARIO: MGSFLOOD_15MIN_3SUBBASIN
Number of Subbasins: 3
Number of Links: 3

---------------------SCENARIO: POSTDEVELOPED
Number of Subbasins: 1
Number of Links: 0

*************Groundwater Recharge Summary ***************
Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: 991242A		54573.040
Subbasin: 991242B		8674.714
Subbasin: 991242C		29545.780
Link: FS_location	0.000	
Link: OC_1	Not Computed	
Link: OC_2	Not Computed	
Total:		92793.530

Total Post Developed Recharge During Simulation

Model Element		Recharge Amount (ac-ft)
Subbasin: All	153.060	
Total:		153.060

Total Predevelopment Recharge is Greater than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 587.301 ac-ft/year, Post Developed: 0.969 ac-ft/year

*************Water Quality Facility Data ***************

---------------------SCENARIO: MGSFLOOD_15MIN_3SUBBASIN

Number of Links: 3

********** Link: FS_location **********

2-Year Discharge Rate : 12.363 cfs

15-Minute Timestep, Water Quality Treatment Design Discharge
On-line Design Discharge Rate (91% Exceedance): 10.04 cfs
Off-line Design Discharge Rate (91% Exceedance): 5.48 cfs

Infiltration/Filtration Statistics--------------------
Inflow Volume (ac-ft): 42155.31
Inflow Volume Including PPT-Evap (ac-ft): 42155.31
Total Runoff Infiltrated (ac-ft): 0.00, 0.00%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Primary Outflow To Downstream System (ac-ft): 42156.29
Secondary Outflow To Downstream System (ac-ft): 0.00
Volume Lost to ET (ac-ft): 0.00

Percent Treated (Infiltrated+Filtered+ET)/Total Volume: 0.00%

---------------------SCENARIO: POSTDEVELOPED

Number of Links: 0

*************Compliance Point Results ***************

Scenario MGSFlood_15min_3subbasin Compliance Link: FS_location
Scenario Postdeveloped Compliance Subbasin: All

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	12.363	2-Year	2.310E-02
5-Year	21.018	5-Year	3.560E-02
10-Year	30.356	10-Year	4.782E-02
25-Year	37.136	25-Year	6.275E-02
50-Year	48.769	50-Year	6.778E-02
100-Year	53.834	100-Year	7.088E-02
200-Year	55.038	200-Year	7.767E-02
500-Year	56.558	500-Year	8.681E-02

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

Attachment 2. MGS Flood Project Report

	CLIENT:	WSDOT		DATE:	2/25/2022
JOB TITLE:	WSDOT NW Region Fish Passage - PHD - Kinman Ck, 991242		TS, PE	JOB # :	A.P3.EV.991242-2-2-2
SUBJECT:	Hydrology		TJ, PE	Sheet # :	1 of 2
Topic:	MGSFlood Cross-sections				

1.0 Final Results

991242 (MGS run as 3-basins)

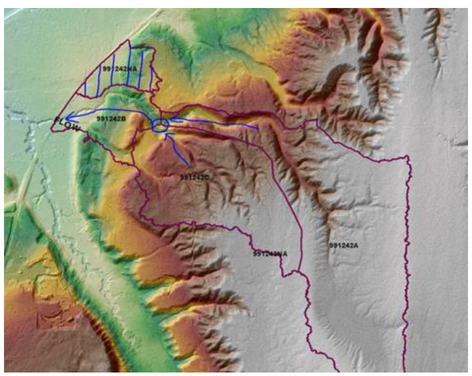
Considering 3-subbasin	991242A		991242B		991242C	
MGS Soil Classifications	**Area (acres)**	**% of total**	**Area (acres)**	**% of total**	**Area (acres)**	**% of total**
Till Forest	269.38	0.78	34.57	0.65	54.58	0.33
Till Pasture	0.00	0.00	0.89	0.02	0.00	0.00
Till Grass	26.24	0.08	6.69	0.12	38.96	0.23
Outwash Forest	16.36	0.05	3.56	0.07	68.26	0.41
Outwash Pasture	0.00	0.00	0.13	0.00	0.00	0.00
Outwash Grass	0.00	0.00	5.72	0.11	4.28	0.03
Wetland	34.55	0.10	0.00	0.00	0.00	0.00
Green Roof	0.00	0.00	0.00	0.00	0.00	0.00
User 1	0.00	0.00	0.00	0.00	0.00	0.00
User 2	0.00	0.00	0.00	0.00	0.00	0.00
User 3	0.00	0.00	0.00	0.00	0.00	0.00
Impervious	0.00	0.00	2.02	0.04	0.31	0.00
	346.53	1.00	53.58	1.00	166.39	1.00

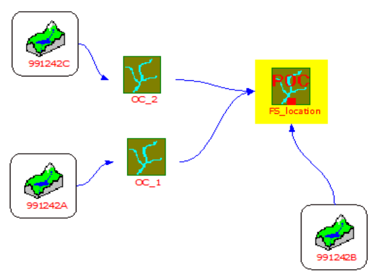
	991242A	991242B	991242C
Percent Canopy Cover:	82%	71%	74%
Percent Impervious:	0.00%	3.78%	0.18%

MGS Flood Results (MGS run as 3-basins)		
Exceedance Probability	**Tr**	***Discharge (cfs)***
0.5	2-Year	12
0.2	5-Year	21
0.1	10-Year	30
0.04	25-Year	37
0.02	50-Year	49
0.01	100-Year	54
0.005	200-Year	55
0.002	500-Year	57

2.0 Climate Change Impact

Climate Change Impact Analysis					
Exceedance Probability	**Tr**	*Climate change adjustment for 2040 (mean)*	*Predicted flow for 2040*	*Climate change adjustment for 2080 (mean)*	*Predicted flow for 2080*
		%	**Discharge (cfs)**	**%**	**Discharge (cfs)**
0.5	2-Year	13	17	16	24
0.01 (100-year flood)	100-Year	38	74	56	84





Attachment 3. USGS Regression Method Calculations

Jacobs	CLIENT:	WSDOT		DATE:	2/23/2022
JOB TITLE:		WSDOT PHDs	BY: TS, PE	JOB # :	W3Y05003
SUBJECT:		Hydrology Model Input Computations	CHECKED: TJ, PE	Sheet # :	1 of 1

Topic: USGS Regression Method - Unnamed Tributary to Kinman

from: https://pubs.usgs.gov/sir/2016/5118/sir20165118_floodqtools.xlsm

documentation: https://pubs.er.usgs.gov/publication/sir20165118

Flood Q Regression Tool. Use to estimate flood discharge in Washington State at ungaged sites based on regional regression equations and user-determined basin characteristics.

DA = Drainage Area, in square miles; P = Average Basin Annual Precipitation, in inches (from PRISM data set, years 1981-2010); CAN = Percent canopy cover (NLCD 2001); AEP = Annual Exceedance Probability; Qu = Flood Discharge, in cubic feet per second at ungaged site for the indicated AEP; PI_L, PI_U= Predition Intervals (L=Lower and U=Upper)

Instructions for using the Flood Q Tool to estimate Flood Discharges at Ungaged Sites using the regional regression equations

Steps	Instructions
1	Select the Regression Region below from the List Box
2	Determine the drainage area, *DA* and the Annual Precipitation, *P* for the ungage drainage basin. If you pick Regression Region 1 or 2, determine the percent canopy cover, *CAN* .
3	Enter these basin characteristic values in the green-shade cells. If the cell changes to red, than the value is outside the range of valid values for this regression. Valid value range listed to the right of the green cells.
4	Rows 23-30 will have the results. Estimated flood discharge, Qu, will be found in column O and the 90% prediction limits for these flood discharges will be found in columns R and T.

Regression Region 1
Regression Region 2
Regression Region 3
Regression Region 4

User determined basin characteristics for ungaged site

Selected Region:		Regression Region 3		Range of values that are valid for the regression
Drainage Area, *DA*	=	0.886	square miles	0.08 - 2605
Annual Precipitation, *P*	=	38.10	inches	33.29 - 168.0
Percent Canopy, *CAN*	=	80	%	value not used in regression

Selected Region: Regression Region 3

Estimate of indicated flood discharge for Regression Region 3 using regional regression equations

AEP		*Q_u, ft³/s	PI_L, in ft³/s	PI_U, in ft³/s
			Prediction Intervals, 90% confidence level	
0.5	=	15.4	7.7	30.9
0.2	=	24.7	12.0	50.7
0.1	=	31.1	14.9	64.7
0.04	=	39.5	18.2	85.8
0.02	=	45.8	20.4	102.6
0.01	=	52.7	23.0	120.5
0.005	=	59.5	25.0	141.4
0.002	=	69.1	27.8	171.8

*rounded to 3 significant figures

Regression Regions in Washington State